THE ENGINEER

NOVEMBER 28, 1952

American Memorial to King George VI

SPEAKING in New York on Monday last, Mr. Lewis Douglas, former United States Ambassador to Britain, announced the establishment of an American fund as a memorial to King George VI. The fund, he said, would be used to enable students from the Commonwealth to engage in study in the U.S.A. Mr. Douglas said that the irresistible force of the events of the past twenty years had established a very special relationship between the Commonwealth of Nations and the U.S.A. It was for the purpose of tightening the bonds which irresistible events, common national interests and a novel international environment made essential, that the memorial fund was being raised to provide financial assistance for young men and women from all Commonwealth countries who might choose to spend a part of their formal education in the U.S.A., and who satisfactorily met the qualifications for their selection. University graduate students would be chosen, but, Mr. Douglas explained, the fund was more particularly designed to assist students in the "more technical disciplines," of which courses in mining, electrical, chemical, and civil engineering, agriculture, irrigation, and journalism were examples. It would also be employed to help young men and women who, having qualified for admission to one of the purely professional schools established in their own land by particular corporations or industries, could meet the specifications for attendance in similar schools in the U.S.A. The fund, it should be explained, is an entirely American one, the management of which is being undertaken by the English-Speaking Union. The aim is to raise at least 500,000 dollars. Initially, it is intended that a minimum of fifty awards shall be made annually, and subsequently to increase that number. Marshal of the Royal Air Force, Lord Tedder, Chancellor of Cambridge University, who was present when Mr. Douglas made his announcement, said that the fund would enable the Commonwealth to make wider use of its scientific skill with the help of American resources for applied science. It would provide an ever-widening channel for the flow of mutual knowledge and understanding.

The Royal Yacht

A MODEL showing the general arrangement of the small hospital ship, which is to be used as a Royal yacht in peacetime has been approved by Her Majesty the Queen. Of Admiralty design, the ship conforms to the rules of Lloyd's Register of Shipping and her construction will generally follow merchant ship practice. The ship's overall length will be 413ft and the length on the waterline 380ft; the maximum beam being 55ft and the moulded depth 32ft 6in, while the maximum draught is limited to 16ft, giving a load displacement of 4000 tons. Single reduction geared turbines, taking steam from two boilers, will drive twin screws to give the ship a cruising speed of 21 knots. She will have a raked bow, cruiser stern and three masts, the Royal Standard will be worn at the main, the flag of the Lord High Admiral at the fore and the Union flag at the mizzen. A stabiliser is to be fitted to control rolling and both a Decca navigator and navigational radar will assist the navigation. The structure above the water line is to be riveted and the ship will be equipped for making voyages in Arctic and tropical waters. At the after end of the ship are the Royal and State apartments, on the shelter and upper decks respectively, while the ship's officers and crew are accommodated forward. As arranged, the ship can be converted into a hospital ship with the minimum of structural alteration, the Royal and State apartments becoming hospital wards, for which air conditioning is being fitted. A helicopter will be able to land on the after end of the shelter deck. The keel was laid at the yard of John Brown and Co., Ltd., in June of this year, much of the double bottom being already erected, and the yacht, which will be launched by Her Majesty in April, 1953, is expected to be completed by the end of that year.

Bankside Power Station

ON Monday last, in the House of Commons, Sir Edward Keeling put some questions to Mr. Geoffrey Lloyd, Minister of Fuel and Power, concerning Bankside power station, London. Sir Edward asked whether the new station had come into action; what its annual consumption of fuel oil would be and how much sulphur that oil would contain; how many tons of sulphur oxides would be formed on combustion; and what proportion of the quantity would be annually discharged into the atmosphere. In his reply, the Minister said that the Bankside station was not yet operating. Its annual consumption of fuel oil was expected to be about 40,000 tons, containing about 1600 tons of sulphur, which would form approximately 3200 tons of oxides on combustion. He thought that about 5 per cent would be discharged into the atmosphere. Sir Edward then wanted to know if the Minister was satisfied that, when the station started work, and, still more, when it was completed, the sulphur oxides discharged from it would not harm St. Paul's Cathedral. About that, the Minister said that he could not give an unqualified undertaking. He was able to say, however, that the Fuel Research Station, the British Electricity Authority and the authorities of St. Paul's Cathedral were installing special instruments to measure the amount of sulphur dioxide discharged.

Safety Rules for Merchant Ships

ON November 19th the "International Convention for the Safety of Life at Sea," which was drawn up in London in 1948, came into force, and to give effect to the Convention new safety rules made by the Minister of Transport under the Merchant Shipping (Safety Convention) Act, 1949, were brought into operation simultaneously. The Convention replaces that of 1929, which now has been denounced by H.M. Government, the denunciation becoming effective one year later. One important requirement is that cargo ships of 500 or more gross tons, engaged in international voyages, must be surveyed once in twenty-four months and possess the Safety Equipment Certificate covering the vessels' life-saving appliances, fire appliances, light and sound signals and distress signals. New cargo ships must also carry stability information. Lifeboats which carry more than sixty people must be mechanically propelled, mechanical hand-propelled boats being rated equivalent to motor boats, but two motor boats must be carried by large passenger liners. Tankers of 3000 gross tons must carry four lifeboats, while yachts over 15 tons burden are required to carry boats to accommodate all on board. Two fire pumps must now be fitted on cargo ships of 1000 gross tons and over, and continuous radio watch must be kept on "distress" frequency on all ships of 1600 gross tons and over, while those between 500 and 1600 gross tons must keep a distress watch for eight hours a day. A radio direction-finder is compulsory on all ships of 1600 gross tons and over, but ships under 5000 gross tons have a year in which to comply. Owners and masters of all United Kingdom ships, wherever they are loaded, are responsible for precautions against the shifting of grain cargoes, and the rules set out the general principles governing the carriage of dangerous goods. Nineteen countries have deposited acceptances with the United Kingdom, and these countries between them own four-fifths of the total world tonnage.

Sand and Gravel Working in N.W. England

THE Ministry of Housing and Local Government has published this week a report by the Advisory Committee on Sand and Gravel, which deals with sand and gravel working over the next fifty years in North-West England. The committee's problem has been to make allocations of land for working which would cause the least possible damage to agriculture and landscape. The report says that the future demand in the region for sand and gravel is estimated at 4,000,000 cubic yards a year, though the committee recommends regular review of that estimate. The report suggests that the damage to landscape caused by gravel workings is not likely to be serious, but on account of the high agricultural value of gravel land in the river valleys, the committee has omitted a number of potential areas in making its recommendations for Lancashire and Cheshire. It is believed that, during the latter half of the fifty-year period mentioned in the report, consumers in Cheshire and in the southern part of Lancashire will have to draw increased supplies of sand and gravel from the Bunter pebble beds of North Staffordshire. The shortage of sand and gravel which is likely to occur in North and Mid-Lancashire in about thirty years' time, the report says, will either have to be met by supplies imported from the West Riding of Yorkshire or consumers will be forced to use alternative materials, such as crushed stone. The report includes also a section dealing with Cumberland, where the committee has estimated that the future demand for sand and gravel will be at the rate of 195,000 cubic yards a year. The recommendations provide for supplies for little more than twenty years, but it is stated that a survey is being made by the Cumberland County Council and the River Board to determine whether gravel dredged from the beds of rivers could help to meet the deficit.

Industrial Developments in Uganda

IN the course of a speech which he made to the Uganda Legislative Council on Thursday of last week, Sir Andrew Cohen, the Governor of Uganda, said that it was proposed to establish an iron and steel industry in the Protectorate. That industry, Sir Andrew explained, would be based on magnetite deposits at Sukulu in the Eastern Province, and would be run by the Uganda Development Corporation, a Government-sponsored organisation. For a start, it was intended to produce pig iron and steel sections in substantial quantities and it was hoped that subsequently ancillary industries would be established. Sir Andrew went on to say that advice received from experts showed that the scheme could be carried through on an economic basis, not only bringing profit to the Development Corporation and any technical partners it might obtain, but also adding substantially to the national income of Uganda. In addition, Sir Andrew stated, the Development Corporation was investigating the possibility of paper manufacturing and the production of glass, pottery and fertilisers. Sir Andrew announced also that steps were being taken in Uganda to develop a wolfram industry. He said that the Ministry of Materials in the United Kingdom was willing to contract to buy all the wolfram produced for five years at current London market prices, subject to a minimum of £12 10s. per long ton delivered in London.

Trans-Canadian and British Railway Experiences

By EDWARD H. LIVESAY

No. III—VANCOUVER TO TORONTO VIA C.N.R.

(*Continued from page 677, November 21st*)

The author has made a number of recent journeys on Canadian and British Railways and his reminiscences of these trips are set out in this series of articles. They began with a comparison of the two transcontinental railways—Canadian National and Canadian Pacific—giving an account of a journey from Victoria to Vancouver via Nanaimo, C.P.R. This run was the prelude to another from Vancouver to Toronto on the C.N.R., which is described here.

THE " Continental " should have left Edmonton at 9 p.m., but actually did so well after midnight. I was snug in my berth so nothing appears in my notebook about events at the great northern metropolis ; in fact, I knew nothing until, drawing up the blind beside my berth and peering out, I found we were spinning along over the genuine prairie, looking very fresh and green under a summer sun. " Cavell " was painted on the side of an elevator, so I knew we were nearing Biggar, the next divisional point, the second since leaving Edmonton—the first had been Wainwright. We came to a stand in Biggar at 6.25 a.m., 3 h late ; that broken drawbar far back in B.C. had left what appeared to be an indelible mark on the schedule. Here I took to the cab, minus breakfast, for the 64-mile run to Saskatoon, finding the engine the same one that had come on at Jasper, 502 miles back in the Rockies ; it would remain on duty until reaching Winnipeg, 535 miles farther east. From this it will be seen that engines make very long runs in Canada—in this case 1037 miles—thanks to rocking and drop-grates, tube cleaners, and " ground crews," who attend to lubrication at divisional points, mechanical stoking, and so on ; these points are never more than 150 miles apart. Though engines do long runs, the crews do not, contrary to impressions I have often found held by railwaymen in Britain. Union rules impose limitations as to mileage, as in other things ; personally I think many of the rules are overdone, and result in " feather-bedding " which is often carried to ridiculous lengths. Crews live at divisional points and only work over the divisions on either side, so they never get more than 150 miles away from home.

The daily and weekly mileage an engineman does is controlled by union rules ; the enginemen who came off the " Continental " at Biggar, for instance, had come from Wainwright, 140 miles, and after standing off a few hours would return there, probably with the westbound " Continental," at 11.15 a.m. The total weekly mileage is very moderate, as are the hours and days per week—certainly not more than an eight-hour day and a five-day week. The unions lay down the law about everything, including pay, and at this safe distance from Canada I openly admit considering enginemen—at any rate " top link men "—are grossly overpaid. For this *I* am mulcted, not the companies—I and a few million other unfortunate citizens—we pay the piper in the shape of constantly increasing fares and freight rates, but we emphatically do not call the tune, which is chosen for us. I do not give the exact figures because I am not sure of them, but they would amaze British railwaymen ; I can chance my arm with £1750 per year, and if any reader considers that an engineman, whether calling himself a driver or an " engineer " is immaterial, is worth that, or earns it, I beg leave to disagree flatly with him. These high wages are nothing Canada need boast of ; on the contrary, they are indefensible, and are only paid because the country is union-governed even more than Britain. Though a Canadian citizen for two-thirds of my life I have not the slightest sympathy with this state of things, considering it one of the many ways in which my adopted country has deteriorated during the forty-eight years I have known it. Neither the country nor the average "worker" has now the respect I used to bestow on both ; the self-reliance of the latter is fast becoming a thing of the past. But I digress.

The run from Biggar to Saskatoon was made at an average of 45 m.p.h., a very representative figure—I believe the C.N.R. has a 60 m.p.h. maximum restriction over these prairie divisions. The load was 1200 tons, unchanged from Vancouver. Chatting with the fireman, who, as usual on a mechanically stoked engine, had plenty of time to be sociable, I asked which he preferred, the feed water heater plus " Elesco " pump, or the exhaust steam injector. He said he did not much mind which he was provided with so long as the so-and-so worked, which, after all, is a very sensible attitude to take up ! I gathered that in winter the injector was more apt to give trouble, as is only to be expected in temperatures that may plummet to 60 deg. below zero ; it is more temperamental, as it were. A feed-water heater is combined with a pump, so the water has to go into the boiler whether it wants to or not, whereas it can only be coaxed in by an injector. Later, wanting more authoritative information about boiler feed equipment, I took the matter up with officials at Montreal, my inquiries including the exact difference between an injector and an " inspirator," a thing which had intrigued me for some time—I opined it might turn out to be one of those American vacuities such as " Transportation" instead of " Ticket " ! It seems that " Inspirator " is merely the trade name for the Hancock injector, which was first manufactured in Boston in 1874. It was so named because it combined both lifting and forcing jets and cones in one, and worked with a closed overflow. Since then injectors have combined all the functions of the " inspirator " and are the same in detail, so the latter word is just a Hancock perquisite.

The respective merits or otherwise of the feed water heater and injector are more difficult to assess accurately. Any device using waste heat, such as exhaust steam, rather than live steam for boiler feed, is attractive, provided no considerable added maintenance cost is involved which might offset the fuel economy gained. The feed pump does not introduce any excessive maintenance burden, considering it is a device in constant use. Cleanliness of the heater elements and the exclusion of oil carried by the exhaust steam from the heater and the tender tank (through the returned condensate) were the major problems, which have been considerably reduced by more efficient oil separators. Arguments have been waged from time to time as to the overall merits of heaters of different types, but numerous tests appear to justify their use.

The virtues of exhaust steam and live steam injectors can be argued about in much the same way as can those of feed-water heaters versus injectors. Low temperatures affect the operation of both to much the same degree, and protective casings are provided where extreme weather conditions are encountered. With regard to " lifting " and " non-lifting " injectors, all modern C.N.R. locomotives are fitted with the latter.

The " Continental " came to a stand in Saskatoon at 8 a.m., still three hours late, having covered the 1101 miles from Vancouver in 36½h, which makes the average speed 30 m.p.h. Here I stopped off ; it had been a pleasant and comfortable journey, but my car, a twelve-wheeler of oldish vintage, had not run quite so quietly and smoothly as one of the latest kinds. Subsequent travel in an assortment of coaches in Britain has proved beyond doubt that the latter run considerably better ; I have been very agreeably surprised at this. Even a very pre-war British coach—possibly pre-First War—such as I have ridden, let us say, over the Oxted-Tunbridge Wells line, where steam trains still operate (thank goodness) and the latest rolling stock is not always found, rides better than the 80-ton " mastodon " which brought me through the Rockies. The permanent way must be chiefly responsible.

From Saskatoon a train was taken north to the old town of Duck Lake, historically interesting as the site of a battle in the Riel rebellion of the 'eighties, when Louis Riel was defeated by regulars under Sir Garnet Wolseley. The soldiers had been brought from the east over the C.P.R., then still under construction, in a matter of days instead of the months that Riel had figured on. But for this the rebellion might have gone differently. The battle took place near the Carlton Ferry, by which I crossed the Saskatchewan River long years ago, and crossed it again on this occasion—apparently by the same ferry.

In the old days I had reached it on foot, after several hours' walking from Duck Lake along a rough trail ; this time I arrived in a Ford V-8, which had wafted

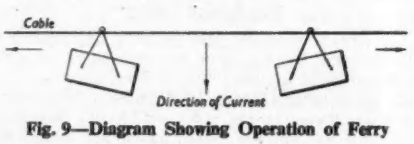


Fig. 9—Diagram Showing Operation of Ferry

me along a surfaced road from the town at 60 m.p.h.—the road had improved, but the town had not. The ferry is a quaint affair, like a barge, guided by a cable, the motive power being the current acting on the craft itself, which is inclined like an otter board, as shown in the diagram Fig. 9, according to which bank of the river the ferryman is aiming at. The road from Duck Lake is a typical prairie " dirt road," made by " grading," or nowadays bulldozing, the soil from the sides or ditches into the middle of the road allowance and leaving the traffic to smooth out and harden it. It is dusty in summer and impossible after rain ; in winter it is frozen and under snow. Only the first few miles of road out of Duck Lake were hard surfaced ; the rest of the way to my destination, a relative's old homestead, I whirled along the dusty trails and through the almost unchanged bluffy country at a mile a minute. My mind went back to

those far-off days when I had hauled wheat in a sleigh over the same roads on a bitter winter day at 2 m.p.h. behind a team of oxen. I swore I would never drive oxen again—and have kept my word. In winter, in this neighbourhood, one crossed the Saskatchewan on the ice ; in spring and autumn, when the ice was breaking up or forming, one did not cross at all. Since there are still no bridges nearer than Saskatoon and Prince Albert, presumably the procedure remains the same to this day.

The next day, from Saskatoon to Tessier, a village 42 miles south-west, on the Goose Lake line, by coach, over a fine concrete road —changed conditions, indeed. It had been only a dirt road in former days, with no motor transport ; only the C.N.R. train once a day, stopping at every station, and off the track so often that this ceased to occasion remark. The train still runs, and with the same timing, but it does remain on the track nowadays—as a rule. It became clear to me, as the coach rushed along at 45 m.p.h., that the day of the small farm in the Prairie Provinces is nearly over. Mechanisation does not suit a farm of 160 or 320 acres, and there never were holdings smaller than this. Machinery is expensive and becomes ever more so ; even if a prairie farmer can manage the initial outlay the same amount of machinery can take care of a larger acreage. So the smaller farms are absorbed by the larger, on which a man with a tractor can work a greater acreage than he could with one or two four-horse teams.

To understand the layout of the prairie landscape, the shape and size of the farms, why the roads always run straight and at right angles, and so on, it should be explained that when the country was opened up from " bald prairie " to wheatland, the surveying was always done in the same way. The land was divided into " townships," of 36 square miles (Fig. 10), and these were subdivided into thirty-six " sections," each of 1 square mile, or 640 acres. " Road allowances " 100ft wide run every mile north and south, and every 2 miles east and west, and though all these allowances are not

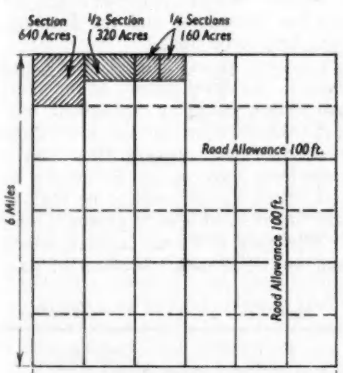


Fig. 10—Plan of Township

necessarily made into actual roads, the land is set aside for them, and they can be constructed where and when local conditions dictate. In the early days the surveyor's stakes were of wood, with the appropriate section markings put on a flattened side ; they also indicated the centre of the road allowances, which were taken out of the acreage of adjacent sections. These stakes were apt to get displaced in various ways, or even burned in prairie fires, with the result a settler might have difficulty in fixing the precise boundaries of his land. An old-timer in the Kinley district told me of the trouble he ran into from this cause when he came into the country and " took up land." He failed to find some of the vital stakes, but by " lining up " with a neighbour's corner posts, which he was assured were accurate, he fixed, as he thought, the edge of the road allowance, built his sod shack, dug a 50ft well with a good inflow of water, and set to work. Later, when, the municipal road gang came along to grade the allowance, my friend's shack was found to be on an adjoining section, and his well in the middle of the road. He had to pull down and rebuild the former, and fill in the latter; after wearily digging another well, this time safely inside his own property, there turned out to be no water in it. His description of what he felt about the whole business, and what he said to the road gang, particularly the latter, remain with me as happy memories to this day ; alas, THE ENGINEER is not a suitable medium for quotations. Life on the prairie in the old days was tough, but one could generally find something, or somebody, to laugh at.

Much the greater area of the prairie provinces was originally taken up by settlers on " homesteads," free land grants of 160 acres, or " quarter-sections," which could be worked by a pair of horses or even oxen. In the old days of this, the " Last Great West," one man with a four-horse team could work 320 acres and keep them in fairly good condition, until weeds crept in and got ahead of him, as they were sure to do sooner or later. (He then sold the place to a new and green arrival, moving on to virgin soil farther west, if possible.) Three-year crop rotation was popular then ; summer-fallow, wheat, and wheat sown on stubble ; wheat was the only crop anyone bothered about as a rule. A " prairie ideal " was a section of land, two four-horse teams, a hired man willing to work a fourteen-hour day and a six-day week,* be content with small wages, and live on salt pork, potatoes, prunes and flies. Flies, with mosquitoes, constituted the Eighth Plague. There were plenty of them in those days—this happy breed of hired men, I mean. They are largely extinct now, though the flies are as plentiful as ever, I believe. Farmhouses nowadays are often equipped with modern conveniences, particularly in the kitchen—varied culinary gear, refrigerators, electricity, telephones, and so on, are commonplace, while cars and better roads bring towns and shops closer to the cooking range and larder, and the hired man is correspondingly better fed. As to his wages, they have soared into the stratosphere, as elsewhere. But as I looked across the familiar landscape and thought of all this, nevertheless I saw it was in many ways the same old prairie of wide open spaces, sun-baked in summer, snow-blanketed in winter, swept by hailstorms and blizzards, no place for the townsman or weakling. It is still essentially a lonely place for the farmer, and particularly the farmer's wife ; their home can easily be isolated for weeks on end when the roads are blocked by drifts, until the snowplough comes along.

Fig. 11—Autumn on the Prairie, Western Canada

Fig. 11 is typical of the prairie in the Fall, after harvest, when every year 100-car freight trains loaded with wheat roll east to the great elevators at Fort William and west to Vancouver. It might have shown, too, a little farmhouse, and a straw pile, golden mounds which used to dot the land in every direction. After threshing was over, they were raised by the separator (threshing machine) blower, to be burned as the only way to dispose of this waste material—a shocking agricultural crime for which the West has had to pay heavily in recent years. These funeral pyres, twinkling brightly in every direction at night, are seldom seen now ; combines leave the straw behind to be ploughed in, a far better way to dispose of it. Yes, the farming methods I knew and practised on the prairie have changed in many respects, and I with them. Never again shall I burn straw stacks, which I hated doing, because I knew it was wrong, but there was no other way of getting rid of the stuff then ; nor handle a six-horse riding plough on a 2-mile land, where three rounds in the morning and two in the afternoon were a day's work. I would sometimes go to sleep on the job and fall off the plough, just as I still fall asleep in the cab. Neither shall I " haul wheat " in a box-wagon into the elevator at Kinley and fall asleep on *that* job and wake up to find myself in a strange barn-yard. Fig. 12 shows a typical standardised prairie station, consisting of ticket and telegraph-operator's offices, baggage room, with the station-agent's quarters overhead and a wooden platform with a couple of passengers ; around it, space and more space.

From Saskatoon to Winnipeg the outlook is much the same as from Edmonton, so there is no need to say anything about it save that the " Continental " was still running on what had originally been the Grand Trunk Pacific track, and had done so right from Jasper in the Rockies. The line crosses that of the C.P.R. on the level near Portage le Prairie, in Manitoba ; on one occasion, when I was travelling on the latter line's " Dominion," we were halted to let the " Continental " have the right of way. Both trains had left Vancouver at

* Plus as much more as he could be induced to do on Sundays. On a prairie farm the Fourth Commandment was often interpreted " Six days shalt thou labour and do all that thou hast to do; but on the seventh thou shalt leave it all to the hired man."—E.H.L.

the same time, covered about 1500 miles and come together again nearly forty-eight hours later. Winnipeg was reached O.T. at 6.10 p.m. and here, midway in the 2930-mile journey from the coast, the " Continental " halted 45 min for a more thorough cleansing and servicing than had been possible at the preceding divisional points; and engines were changed. At 6.45 p.m. running was taken up again on the next lap of the 1207 miles to Toronto.

To the Manitoba/Ontario boundary, 100 miles, it is still prairie and wheat country ; dead flat, until suddenly rock outcrops appear and one enters upon what to me is the most uninteresting and monotonous stretch of the whole trip from the Pacific. One runs through endless vistas of scrubby trees and rocks, among which are innumerable little lakes, muskegs, rivers and a succession of shack-towns, crude and ugly to a degree, not a single one of any size or much importance until Sudbury is reached, 1000 miles east. Unlike the C.P.R., the line does not skirt Lake Superior, where the scenery is rather fine ; the train runs on hour after hour through exactly the same sort of bush country and one begins to wonder if it will ever end, and when one will emerge into something worth looking at. As far as Nakina (Fig. 13) it is still the ex-G.T.P. line, but there the " Continental " picked up the old Canadian Northern route, which is followed through to Toronto. The same 4–8–2 type of engine (Fig. 6) used right from the coast, handled the train ; I took to the cab once or twice during daylight hours, but there was really nothing of importance to record. The track, well kept and with 100 lb steel, laid out with curvature of large radius and the easiest of gradients everywhere—no double-heading had been indulged in right from Vancouver despite the 1200-ton load—gave riding that was correspondingly good. But it was monotonous, looking hour after hour at the never-changing bush, good for pulp-wood but useless for lumber, through which the train travelled at 45 m.p.h. or less ; I preferred my sleeper, or one of the new " coaches " (Fig. 14), in which I rode for some time as a change: verdict, very good. At any rate, I could safely fall asleep in those " reclining seats," which could be adjusted to allow one lying almost at full length. The glass partition seen in the picture separates the twenty-eight-passenger smoking compartment from the thirty-two-seat non-smoking section, the whole, of course, being air-conditioned. But though somewhat better riding than the older Tourist sleeper, neither vehicle was so smooth running as I have subsequently found average British rolling-stock to be.

The location of the old, beautifully graded Grand Trunk Pacific line is shown

Fig. 12—Typical Prairie Station

in Fig. 13. Built at a cost of scores of millions, it continues east from Nakina through Cochrane and Santerre to Quebec, where it crosses the St. Lawrence by the great Quebec bridge, which gave so much trouble before it was finally completed. It collapsed once—it was designed by the American, Cooper, who had sneered at the Forth Bridge for having thousands of tons of unnecessary steel in it. An unfortunate comment—the Forth Bridge has stood for over half a century, whereas Cooper's *magnum opus* fell down before it was finished. It was then redesigned by an international group of engineers with Fitz-Maurice as its chief, but even then misfortune pursued it, the centre span joining the two cantilevers falling while being raised into position. Finally, it was completed and stands majestically spanning the great river, but there is very little traffic over it. This applies also to the whole 848-mile stretch from Nakina to Quebec, as the following shows : Nakina-Hearst, two passenger trains per week in each direction ; Hearst-Cochrane, six passenger trains per week in each direction ; Cochrane-Quebec, six passenger trains per week in each direction.

A number of additional local trains run over certain intermediate sections between Cochrane and Quebec, but in spite of this, traffic is, to say the least, very light over such a road, built at great cost and with high hopes. " Those were the days " of tremendous optimism as to Canada's growth and population—now another similar era has arrived, but this time I would say there is greater justification. But I am sure no more transcontinental railways will be built !

Through this wild country the " Continental " continued eastward, myself generally in the sleeper, well cared for and entertained by the porter, a newly arrived English ex-railwayman, rather homesick and wistfully talking of his past on I forget which line, and very interested in my forthcoming locomotive experiences, the next of which was to be on the " Inter-City Limited " from Toronto and Montreal, Canada's fastest and heaviest long-distance train. The " Continental " ultimately came to a stand in Toronto's great Union Station at 7 a.m. O.T., having taken 80 h from Vancouver, which made the average speed for the 2778 miles 34·6 m.p.h. My personal travelling time, however, had been ten days, for which the Saskatoon and district interlude had been responsible.

Since writing this article it occurred to me that as the brief reference in the first part of it to the genesis of the Canadian National Railway was only based on memory, and that even Homer was known to nod, I had better look up the whole story in official records, and was relieved to find my memory had not let me down. The story is very interesting and bears a little expansion, as follows, the data being taken from the said official sources.

The first Canadian Railway was 14½ miles long, connecting La Prairie and St. Johns, on the Richeleu River ; it was opened in 1836. The Grand Trunk was chartered in 1852 and went on expanding until the Dominion Government took over a number of lines and built the Intercolonial from the eastern end of the Grand Trunk through New Brunswick and Nova Scotia to the Atlantic. The provision of railways was one of the terms of the British North America Act, which united the Provinces, and the Intercolonial was the first to be built.

In the early years of the century, anxious to share in the development of the West, the Grand Trunk made an agreement with the Federal Government for the joint construction of a railway linking East and West. The western division, to be known as the Grand Trunk Pacific, was to be built by the Grand Trunk, and was to extend 1748 miles from Winnipeg to Prince Rupert, which was chosen as the terminal because of its deep-

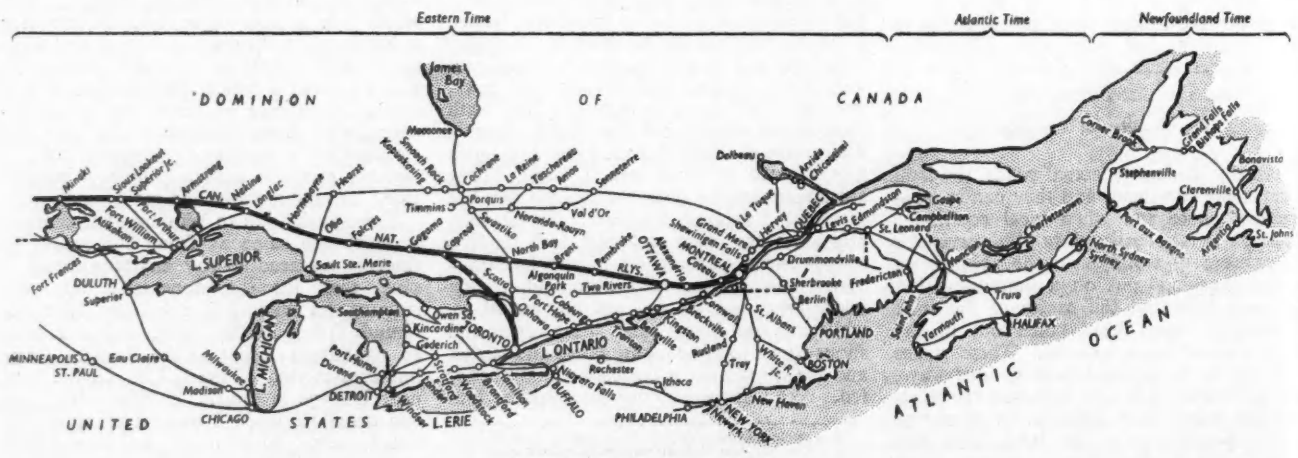


Fig. 13—C.N.R. Eastern Division

Fig. 14—Coach—C.N.R.

water harbour and because it was closer to the Orient than any other port on the Pacific coast. The eastern division was to be built by the Canadian Government and was to extend eastward from Winnipeg to Moncton. The line was to be known as the National Transcontinental and, on completion, was to be leased to the Grand Trunk Pacific. It was finished in 1913, but owing to financial difficulties the Grand Trunk failed to keep the agreement—in other words, it threw up its hands, as I stated in the first part of this article—and the Government had to operate it. Between them, the G.T. and G.T.P. had 7500 miles of railway, ships on the Pacific, large grain elevators at ocean terminals and on the Great Lakes, and had built a number of splendid hotels. In fact, everything was there except the traffic to make all this pay.

Meanwhile another great transcontinental railway had come into existence, the Canadian Northern, which in 1901 had only 971 miles of track, serving a useful function hauling grain and so on. But its promoters, Mackenzie and Mann, were not satisfied until by 1915 they had extended it and themselves, like the frog in the fable, to more than 9000 miles between Montreal and the Pacific, using mostly British capital—as had also the Grand Trunk. Then came the first world war, both companies got into a hopeless mess and collapsed—that is, the frog blew up. Neither should have been built in the way they both were; they would have collapsed any way, war or no war. The Government, the largest creditor, had to take them over. In 1919 the Canadian National Railway was incorporated to operate the Canadian Northern and all other railways already or about to become the property of the Dominion; in 1920 the Grand Trunk Pacific was added, and in 1923 the Grand Trunk was also roped in. The result was the Canadian National Railway as it is to-day, and the Canadian people became the owners and operators of one of the greatest railway systems in the world, with 24,150 miles of first main track, 9000 miles of secondary, yards, sidings, and spurs, 5000 stations, 2730 locomotives, 3512 passenger cars, 108,000 freight cars, &c. &c., and the privilege of paying the losses. It will be seen this is not the company's fault—the Government *had* to repair and reinflate the skin when the frog exploded.

(To be continued)

Stress and Plastic Strain Relations of a Magnesium Alloy*

By A. E. JOHNSON, D.Sc., M.Sc.Tech., M.I.Mech.E., and N. E. FROST, B.Sc., A.M.I.Mech.E.

The work described in this article forms part of a general research into the short-time, combined-stress properties of metallic alloys previously used in a combined stress creep programme. The article describes tests made under complex stress systems on a nominally isotropic magnesium alloy at temperatures between 20 deg. and 150 deg. Cent. The programme entailed tests at 20 deg. Cent. under pure tension, pure torsion and combinations of tension (t) and torsion (s) of ratios t/s=0·2, 0·47, 1·0 and 3·64, and also at 150 deg. Cent. under pure tension, pure torsion, and combined tension and torsion ratios of 0·2, 0·41, 0·8 and 3·25. Additionally, tests at 50 deg. and 100 deg. Cent. and at a t/s ratio of about 1 were made.

SINCE plastic strain is associated with the initial stages of creep under combined stress systems at elevated temperatures, it is necessary to supplement the combined stress creep work already done, by further work to determine stress/plastic strain relations over stress and temperature ranges wide enough to include those previously used in the creep tests. It is intended for the time being to limit the scope of the programme to meet this particular need. This can be done by making tests in pure tension, pure torsion and combinations of tension and torsion applied under conditions of simple loading, i.e. the ratios of principal shear stresses are retained at constant values throughout any particular test. Such loading conditions, of course, preclude discrimination as between the application of "deformation" and "flow" types of theory to the experimental results since both varieties give the same results with simple loading. At a later stage in the programme should opportunity arise some attention may be given to this additional aspect of stress/plastic strain relations; but initially the work on all materials will be directed towards satisfying the primary object mentioned above.

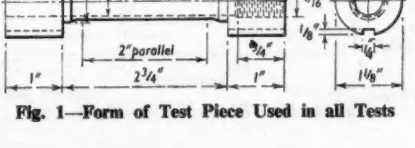


Fig. 1—Form of Test Piece Used in all Tests

While considerable attention has been given by investigators to the stress/plastic strain relations of metal aggregates at normal temperatures, little corresponding work has been carried out at elevated temperatures. In fact, the only work known to the authors is that carried out at the N.P.L. on 0·17 per cent C steel at 350 deg., 450 deg. and 550 deg. Cent., in which owing to the lack of a suitable machine at that period, the work had to be confined to pure tension and torsion tests only.

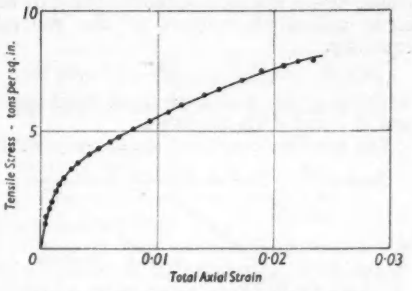


Fig. 2—Pure Tensile Test at 20 deg. Cent.

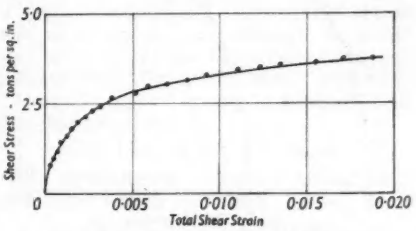


Fig. 3—Pure Torsion Test at 20 deg. Cent.

Since that time, however, a combined tension and torsion machine has been designed and built at the N.P.L., and the work to be described in this article has been performed in this machine. Incidentally, it is intended eventually to supplement the work referred to above by combined tension and torsion tests in the new machine on the 0·17 per cent C steel in question. Meanwhile, it is useful to recount the conclusions reached in this previous work. Briefly, they

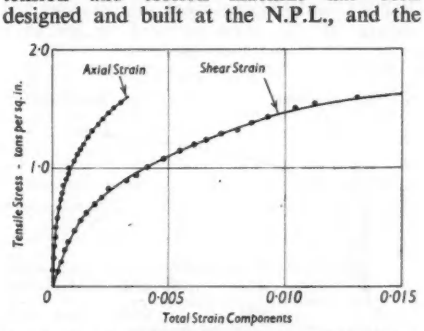


Fig. 4—Test Ratio Tension to Torsion 0·47 at 20 deg. Cent.

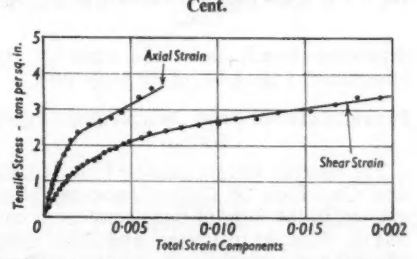


Fig. 5—Test Ratio Tension to Torsion 1·0 at 20 deg. Cent.

* Communication from the National Physical Laboratory.

were as follows. The 0·17 per cent C steel had probably behaved anisotropically under the relatively high plastic strains of the short-time tension and torsion tests. The criterion of yielding or elastic failure for the material between 20 deg. and 550 deg. Cent. was apparently the shear strain energy or Von Mises-Heneky criterion, and the stress-plastic strain relations appeared likely to be some anisotropic variant of the general equations :

$$\varepsilon_1 = A[\varepsilon(\sigma_1-\sigma_2)^2]^m[(\sigma_1-\sigma_2)^n-(\sigma_2-\sigma_1)^n], \text{ \&c.}$$

where ε_1, σ_1, &c., have their usual significance and m, n and A are constants.

The previous combined stress creep work

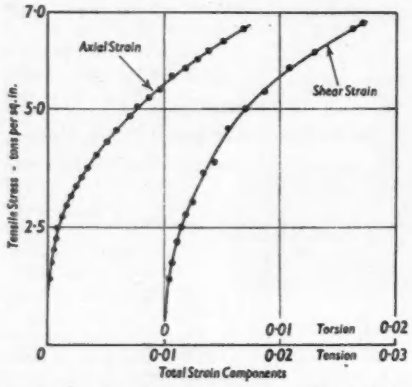


Fig. 6—Test Ratio Tension to Torsion 0·2 at 20 deg. Cent.

on the magnesium alloy concerned in the present article was conducted at 20 deg. and 50 deg. Cent. Accordingly, it was planned to include these temperatures in the current programme ; but in view of the fact that preliminary tensile tests had indicated that the change in nature of the stress/plastic strain characteristics might not be anything like as significant as the change of creep characteristics between 20 deg. and 50 deg. Cent., it was decided to extend the range of tests to 100 deg. and 150 deg. Cent., the number and nature of the tests at each temperature

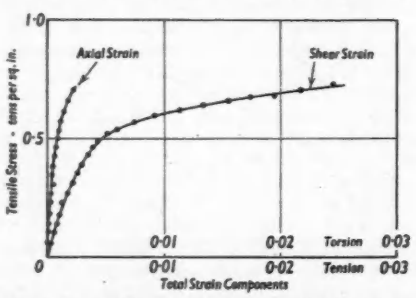


Fig. 7—Test Ratio Tension to Torsion 3·64 at 20 deg. Cent.

depending largely upon the trend of the information arising out of the early tests.

Particulars of the Magnesium Alloy Tested

The material was supplied by F. A. Hughes and Co., Ltd., of Clifton Junction, Manchester, in the form of three continuous cast billets, 12in in diameter and 12in long. Microscopic examination of the material indicated a satisfactory small grain size after heat-treatment at 420 deg. ±5 deg. Cent. for four hours, the temperature then being raised to 525 deg. Cent. and maintained at this temperature ±5 deg. Cent. for four hours, before cooling to room temperature in about ten hours.

The material had been shown to be in a closely isotropic state by the results of the work of the combined stress creep programme, and this was taken to mean that an assumption of initial isotropy could be made in the stress/plastic strain tests to be described.

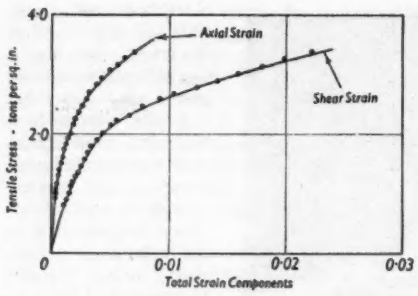


Fig. 8—Test Ratio Tension to Torsion 1·13 at 50 deg. Cent.

Details of the material are given in Table I.

Table I—*Details of Material Used*

Material	Magnesium alloy
Size	Two billets of length 12in and diameter 12in
Heat-treatment	420 deg. Cent. ±5 deg. Cent. (788 deg. Fah. ±9 deg. Fah.) for four hours, furnace cooled to room temperature in about ten hours ; heat-treatment carried out in an atmosphere of sulphur dioxide
Composition, per cent :	
Zinc	<0·05
Aluminium	2·0
Silicon	0·02
Copper	<0·01
Manganese	0·03
Iron	<0·04
Tin	<0·03
Magnesium	Remainder

Form and Disposition of Test Pieces

The whole of the test pieces used in the investigation were machined from blanks cut

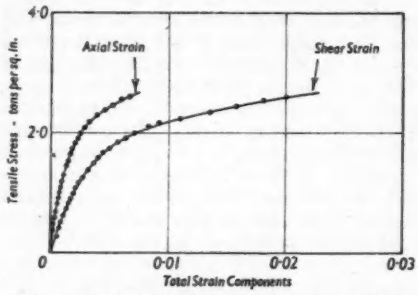


Fig. 9—Test Ratio Tension to Torsion 1·14 at 100 deg. Cent.

longitudinally from the same continuous cast billet.

The form of the test piece used is shown in Fig. 1. The specimens were externally (only) machined to within $\frac{1}{16}$in of final dimensions, and then the heat-treatment described above was given. Boring and keyway cutting was carried out subsequently. The wall thickness of the specimen was 0·030in±0·0005in over a 2in parallel portion. Oxidation over the range of temperatures used was negligible during the period of the tests, and accordingly no correction of stress values due to this cause was necessary.

Outline of Experimental Work

The original programme entailed tests at 20 deg. Cent., under pure tension, pure

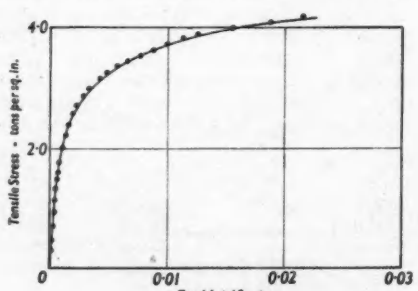


Fig. 10—Pure Tensile Test at 150 deg. Cent.

torsion and combinations of tension t and torsion s of ratios t/s=0·2, 0·47, 1·0 and 3·64, and also at 150 deg. Cent. under pure tension, pure torsion and combined tension and torsion ratios of 0·2, 0·41, 0·8 and 3·25. The results of the work indicated that between 20 deg. and 150 deg. Cent. a very considerable difference in the nature of the stress/strain relations occurred. It was accordingly decided to trace the path of this change with rising temperature by tests at 50 deg. and 100 deg. Cent. and t/s ratio about 1.

It was necessary to select a comparable rate of stressing in all tests. Obviously, this cannot be done in the case of general stress tests except by assuming some arbitrary stress criterion of equivalence of the various

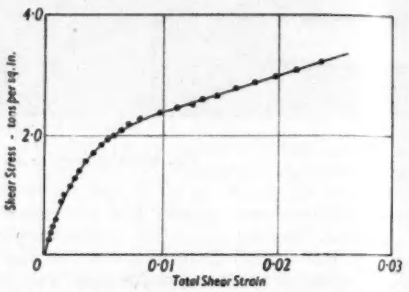


Fig. 11—Pure Torsion Test at 150 deg. Cent.

stress systems. In the light of available experimental evidence the criterion of octahedral stress was in this series of tests assumed as being likely to be not too far from the actual truth. Accordingly, in the tension tests a stressing rate of 0·08 tons per square inch was chosen, and in all other tests a rate equivalent to the octahedral stress rate in tension. Obviously, deviations of this criterion from the truth would give rise to scatter of individual tests relative to each other.

Theoretical Forms of Relations for Time-Independent Plastic Strain

The great bulk of the theories of plasticity may be grouped into two types, the so-called

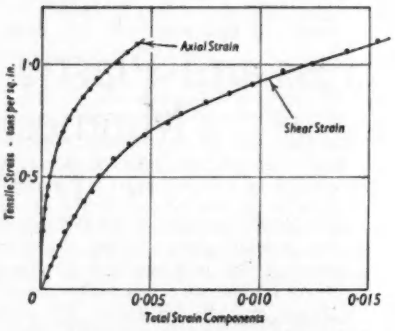


Fig. 12—Test Ratio Tension to Torsion 0·41 at 150 deg. Cent.

" deformation " and " flow " theories. Both types of theory assume that the relations between stress and strain are governed by one law during loading and by another (the elastic law) during unloading. Loading and unloading are defined in terms of the increase or decrease of some rotationally invariant function of the stresses, those generally used being the maximum shear stress, and octahedral shear stress, although it appears to be a fact that although the criterion of maximum shear stress has been widely used to appraise results no actual set of theoretical equations involving this function has been used. The two types of theory differ chiefly in that the deformation theories propose laws giving plastic strain in terms of applied stress, whereas flow theories

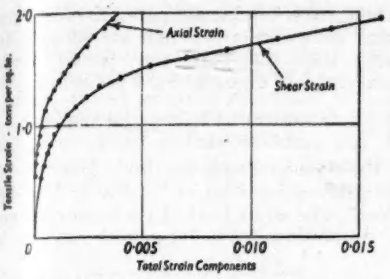


Fig. 13—Test Ratio Tension to Torsion 0·8 at 150 deg. Cent.

propose laws giving increments of plastic strain in terms of applied stress, and increments of applied stress.

In the case of deformation theories, assumption is made of coincidence of principal axes of stress and plastic strain, while flow theories assume coincidence of the principal axes of stress, and the increments of plastic strain.

From the point of view of the present series of tests (as pointed out in the introduction), no distinction can be made between deformation and flow theories, since the conditions of loading are such that all stress ratios remain unchanged throughout the course of each test, and in these circumstances the two types of theory give identical results. Accordingly, in the brief statement which follows of the forms of equation which have been suggested, the deformation type of equation is adhered to, but the analogue in the case of flow theories is in general fairly obvious.

Several of the suggested forms have been used in the previous creep work, and are quite familiar. These, of course, comprise the general Prager equation :

$$\varepsilon = \int (J_2, J_3^2)[p(J_2, J_3^2)J_2(S^3 - {}^2/_3 J_2 I) + q(J_2, J_3^2)S]$$

where ε is the plastic strain tension, S the stress variation tension, of principal values S_1, S_2, S_3 and S_3, $J_1 = \frac{1}{2}(\Sigma S_1^2)$, $J_3 = \frac{1}{3}(\Sigma S_1^3)$, p and q are polynomials in J_2 and J_3, f is a function of J_2 and J_3^2.

Simplifications of these equations which have been considerably applied to room temperature data, are the St. Venant–Von Mises, and the Bailey types of equation, viz.:

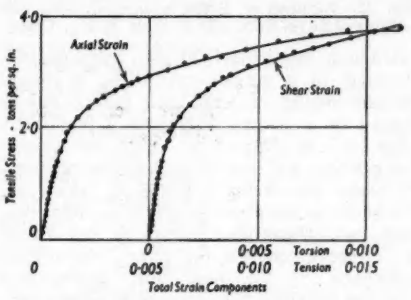


Fig. 14—Test Ratio Tension to Torsion 3·25 at 150 deg. Cent.

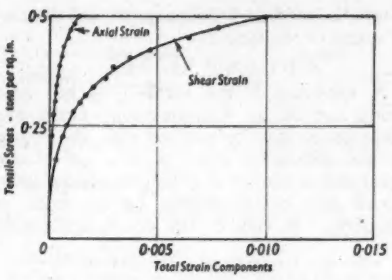


Fig. 15—Test Ratio Tension to Torsion 0·2 at 150 deg. Cent.

(1) $\varepsilon_1 = A[(\sigma_1 - \sigma_2) - (\sigma_3 - \sigma_1)]$, &c.

(2) $\varepsilon_1 = A[(\sigma_1 - \sigma_2)^n - (\sigma_3 - \sigma_1)^n]$, &c.,

where n is a constant.

A in these cases has invariably been taken as a function of the octahedral stress, or, in particular cases, as an arithmetical constant. There is, however, no reason why a function of the maximum shear stress should not be used as an alternative, although, as stated previously, there does not appear to be any evidence that it ever has been. Equations (1) and (2) may obviously be generalised to the respective forms :

$$\varepsilon_1 = [\Sigma A][(\sigma_1 - \sigma_2) - (\sigma_3 - \sigma_1)], \text{ &c.},$$

where ΣA represents a sum of invariant functions. Likewise in the case of (2),

$$\varepsilon_1 = [\Sigma A\{(\sigma_1 - \sigma_2)^n - (\sigma_3 - \sigma_1)^n\}],$$

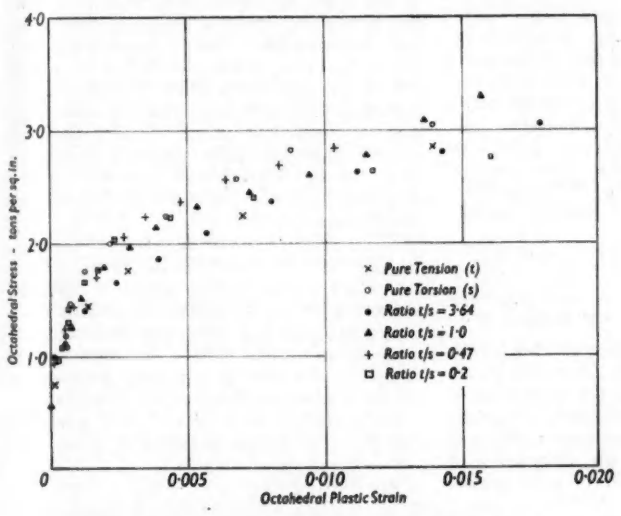

Octahedral Stress - tons per sq. in.
Pure Tension (t)
Pure Torsion (s)
Ratio t/s = 3·64
Ratio t/s = 1·0
Ratio t/s = 0·47
Ratio t/s = 0·2
Octahedral Plastic Strain

Fig. 16—Relation Octahedral Stress—Octahedral Plastic Strain at 20 deg. Cent.

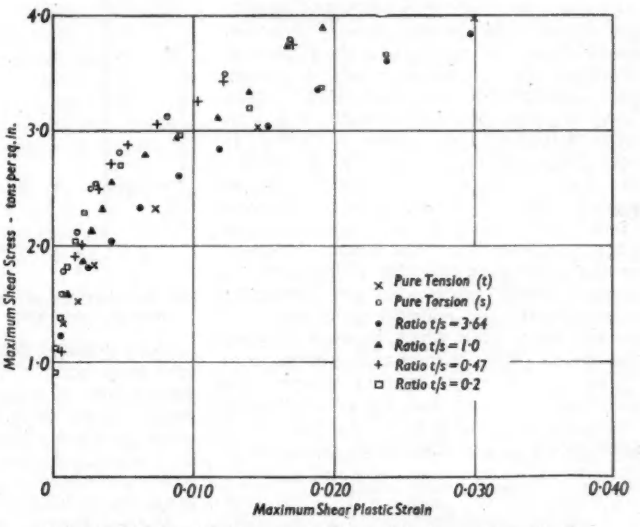

Maximum Shear Stress - tons per sq. in.
Pure Tension (t)
Pure Torsion (s)
Ratio t/s = 3·64
Ratio t/s = 1·0
Ratio t/s = 0·47
Ratio t/s = 0·2
Maximum Shear Plastic Strain

Fig. 17—Relation Maximum Shear Stress—Maximum Shear Plastic Strain at 20 deg. Cent.

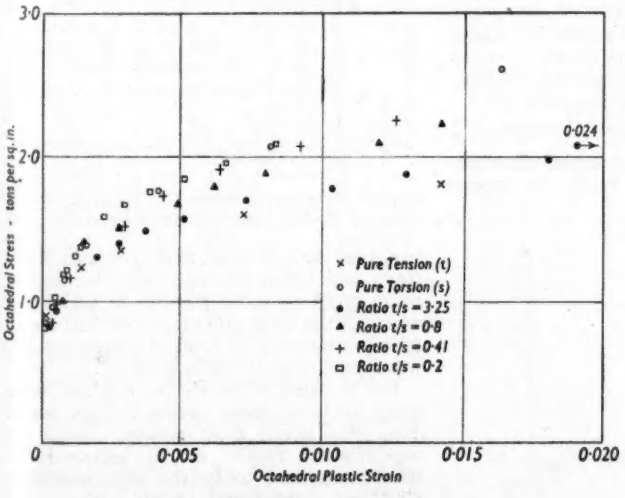


Fig. 18—Relation Octahedral Stress—Octahedral Plastic Strain at 150 deg. Cent.

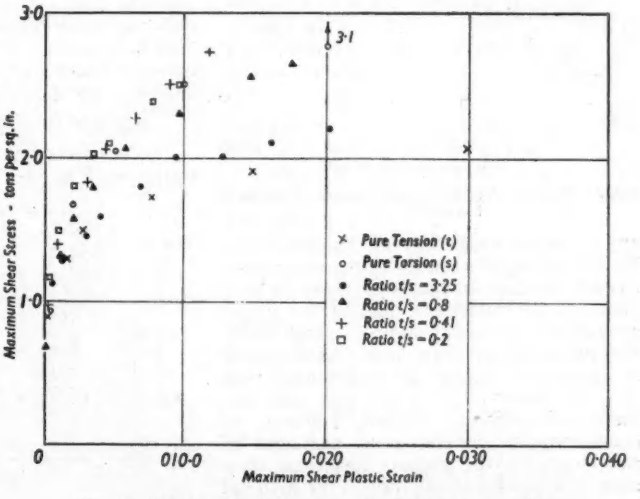


Fig. 19—Relation Maximum Shear Stress—Maximum Shear Plastic Strain at 150 deg. Cent.

where the term in brackets represent the sum of terms of the type :

$$A_N\{(\sigma_1-\sigma_2)^N-(\sigma_3-\sigma_1)^N\}.$$

A variation in the form of A has been made use of by Cunningham, Dorn and Thompson, who considered that the plastic strains depended upon a function of the shear strain energy of octahedral shear stress above that corresponding to the limit of elasticity. In view of the doubt concerning

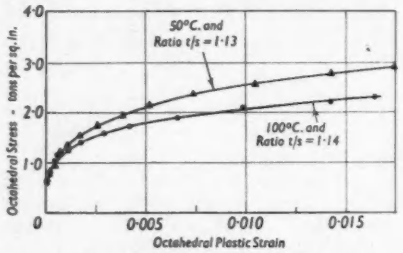


Fig. 20—Relation Octahedral Stress—Octahedral Plastic Strain

the real existence of an elastic limit in many materials particularly at high temperatures, the theory obviously rests on somewhat dubious premises. However, these equations have the form :

$$\varepsilon_1=A\left[\frac{\{\Sigma(\sigma_1-\sigma_2)^2\}^{\frac{1}{2}}-\sqrt{2}\sigma_0}{\{\Sigma(\sigma_1-\sigma_2)^2\}^{\frac{1}{2}}}\right] \cdot [(\sigma_1-\sigma_2)-(\sigma_3-\sigma_1)], \text{ &c.,}$$

where σ_0 refers to the limit of proportionality and A is an arithmetical constant. Obviously, similar varieties of equation can be elaborated involving the terms $[(\sigma_1-\sigma_2^n)-(\sigma_3-\sigma_1)^n]$, and functions of maximum shear stress.

Apart from the deformation and flow types of theory a third variety of theory has been proposed by Batdorf and Budiansky the formulation of which they state was guided mainly by physical considerations with respect to the mechanism of plastic deformation. The theory is based on the assumption that slip in any direction along parallel planes of any particular orientation in the material gives rise to a plastic shear strain which depends only on the history of the corresponding component of shear stress. The relation between this plastic shear strain, and the corresponding stress can be determined from the tensile stress strain curve. The plastic strain due to

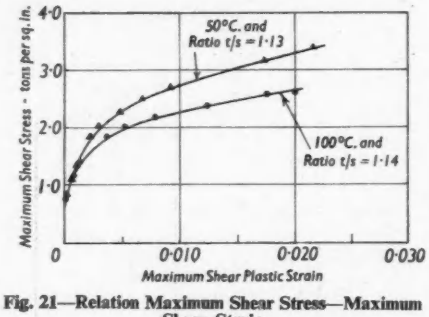


Fig. 21—Relation Maximum Shear Stress—Maximum Shear Strain

any system of applied stresses is then found by considering the history of the component in each direction of the shear stress on each plane of the material ; finding the corresponding plastic shear strain ; transforming this plastic shear strain into plastic strains in some fixed system of co-ordinates and summing over all slip direction and slip plane orientations. Instead, however, of considering the material as an aggregate of small crystals, the authors formulate their stress/strain relations as though the material were a continuum. Obviously, this compromise is a serious objection to the use of

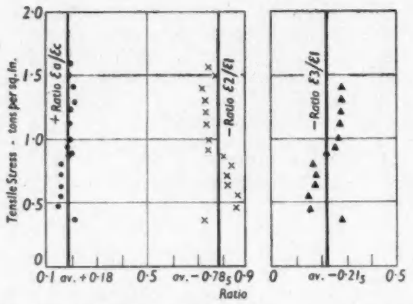


Fig. 22—Variation of Ratios $\varepsilon_0/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress at Stress Ratio $t/s=0\cdot47$ at 20 deg. Cent.

this theory particularly at high temperatures. Applied to a single crystal the proposed process would be valid and useful, but in regard to a normal aggregate it manifestly neglects the important effect of crystal boundaries, and the mere presence of many mutually interfering crystals in modifying the nature of the stress/plastic strain relations, and can, therefore, hardly be considered an improvement on the purely rheological approach of the flow and deformation theories in which the material is simply considered as a continuum. As opposed to these theories this type of theory suffers from the practical difficulty of presenting in general integrals which are very difficult, if not impossible, to solve analytically, and

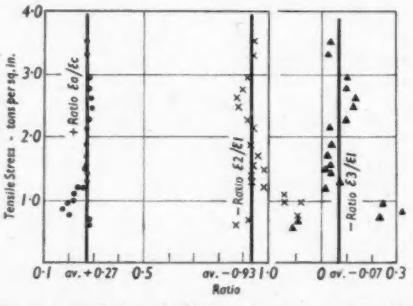


Fig. 23—Variation of Ratio $\varepsilon_0/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress at Stress Ratio $t/s=1\cdot0$ at 20 deg. Cent.

if the alternative graphical means be used a very great bulk of work is necessary in the general case of a material, the limit of proportionality of which is relatively low compared with the stresses reached in the tests as a whole. In view of the rather hybrid bases of the theory this bulk of work cannot readily be justified.

The presentation of the equations of this theory, like that of the Cunningham theory, is in terms of the excess of the current stress over the elastic limit stress, envisaging slip only on those planes in which the elastic limit is exceeded. In view of the above objections to this theory, it has not been used in analysing the results of this present work.

Results of Experimental Work

The results of the tests undertaken are shown in Figs. 2–15 in which the experi-

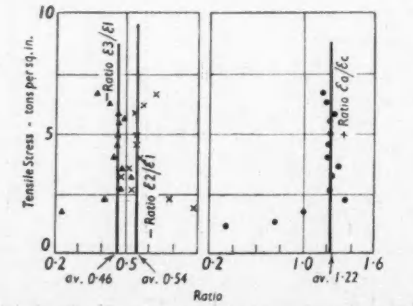


Fig. 24—Variation of Ratios $\varepsilon_0/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress at Stress Ratio $t/s=3\cdot64$ at 20 deg. Cent.

mental stress/total strain curves for axial and shear components of strain are shown. In most tests the maximum plastic strain measured is of the order 1 to 2 per cent.

Discussion of the Results of Experimental Work

Criterion of Departure from Elasticity of the Magnesium Alloy at 20 *deg. to* 150 *deg. Cent.*—The stress level of the apparent limit of proportionality in these tests was low in

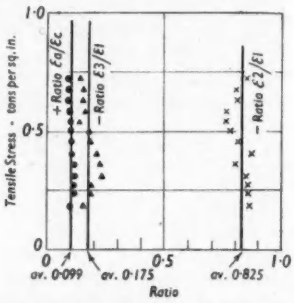


Fig. 25—Variation of Ratios $\varepsilon_0/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress at Stress Ratio $t/s=0\cdot2$ at 20 deg. Cent.

comparison with the stress corresponding to the degree of plastic strain investigated. In the course of the tests the opinion was formed that particularly at temperatures above room temperatures no real limit of proportionality existed, the apparent region of this stress appearing likely to depend very much upon the sensitivity of the extensometer and torsionmeter used. Accordingly, no effort has been made to define a precise criterion of departure from elasticity for the material. Nevertheless, general consideration of very low proof stresses made it evident that any such criterion would be likely to be intermediate between that of octahedral shear stress, and that of maximum shear stress.

Stress-Plastic Strain Relations at 20 *deg.*, 50 *deg.*, 100 *deg. and* 150 *deg. Cent.*—Consideration of the various forms of equation suggested by the theoretical treatments mentioned in a previous paragraph indicated that a variety of critical plots of the experimental data might be made in an attempt to ascertain the form of the stress plastic strain relations.

Accordingly, such plots were made of functions of either octahedral stress and

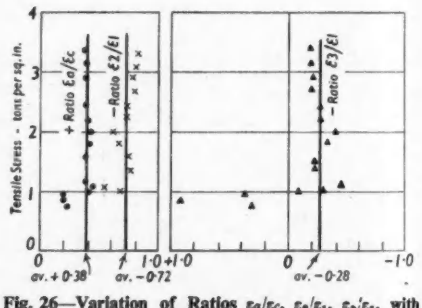


Fig. 26—Variation of Ratios $\varepsilon_0/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress at 50 deg. Cent. and Stress Ratio $t/s=1\cdot13$

strain on the one hand, and maximum shear stress and strain on the other, due regard being given to those theories in which the excess of the stress concerned over the corresponding stress at the limit of proportionality was regarded as the stress criterion.

For the sake of brevity the whole of these plots have not been shown in this paper. The plots which most precisely fitted the experimental results at all temperatures, which happened to be the log. octahedral stress/log. octahedral strain plots are shown in Figs. 33–36, while in Figs. 16–21 the simple plots of octahedral stress against

octahedral strain, and of maximum shear stress against maximum shear strain are given and illustrate one or two trends which are common to all the plots made.

First, it will be noted that there is in all cases a fanning out of the curves in which the pure torsion, on the one hand, and the pure tension tests, on the other hand, tend to set the limits. This fanning out is greater

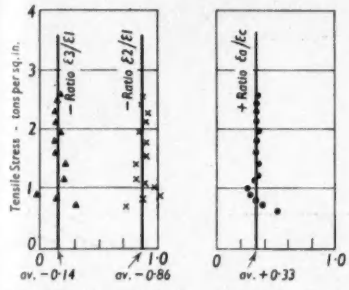


Fig. 27—Variation of Ratios $\varepsilon_a/\varepsilon_1$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress at 100 deg. Cent. and Stress Ratio $t/s=1\cdot14$

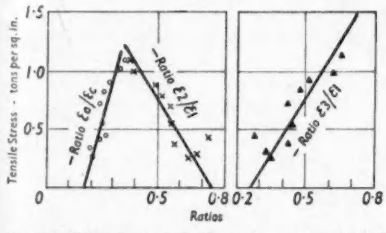


Fig. 28—Variation of Ratios $\varepsilon_a/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress Ratio $t/s=0\cdot41$ at 150 deg. Cent.

in the case of maximum shear stress than octahedral stress, and this was a feature of all plots. Accordingly, the octahedral stress strain criterion was regarded as being the more representative of this material.

Now the fanning out of the curves indicates the existence of some degree of anisotropy which, for the complete exploration of stress-plastic strain relations it is necessary to determine.

The most direct indication of the variety

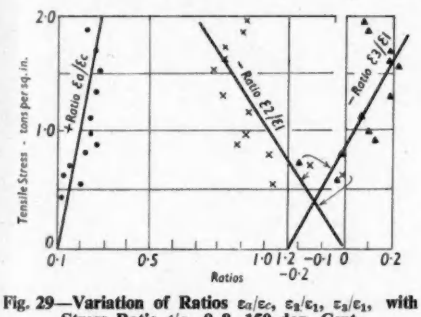


Fig. 29—Variation of Ratios $\varepsilon_a/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress Ratio $t/s=0\cdot8$, 150 deg. Cent.

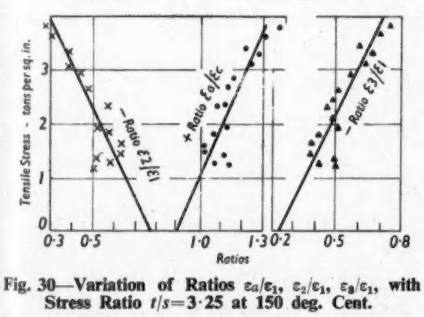


Fig. 30—Variation of Ratios $\varepsilon_a/\varepsilon_1$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress Ratio $t/s=3\cdot25$ at 150 deg. Cent.

and order of anisotropy may be obtained from a consideration of the ratios of the axial and shear plastic strains $\frac{\varepsilon_a}{\varepsilon_c}$, and also of the related ratios of the principal plastic strains $\varepsilon_2/\varepsilon_1$ and $\varepsilon_3/\varepsilon_1$. The first ratio should in the case of an entirely isotropic material vary little from the value $t/3s$.

These various ratios are presented graphically in Figs. 22–31. Figs. 22–27 deal with the temperatures 20 deg., 50 deg. and 100 deg. Cent., and since the relations at these temperatures present certain features which do not arise at 150 deg. Cent., they will be considered together. It will be noted that in all cases at the lowest stresses there is some scatter of the points. This is presumably associated with the fact that initially, and over a range of low stresses more or less complete isotropy is preserved which gradually, as the stress rises, merges into an anisotropic relation. However, above the lower range of stresses, the values at all three temperatures tend to become steady. It was evident, therefore, that a variety of anisotropy of the type $\varepsilon_1\propto[A(\sigma_1-\sigma_2)-C(\sigma_3-\sigma_1)]$, &c., with constant values of A, B and C (at any rate, in individual stress systems) was likely to reasonably represent the tests.

Consideration of the results in detail indicated that, in fact, at all three temperatures the constants A and C were unity, and the values of constant B varied between relatively narrow limits with individual stress systems.

Thus, at 20 deg. Cent. the values of B varied as follows :—

Stress system	Value of B	
Pure tension	1	
$t/s=0\cdot2$	0·8	Average value 1·1
$t/s=0\cdot47$	0·7	
$t/s=1\cdot0$	2·2	
$t/s=3\cdot64$	0·7	
Pure torsion	1	

while at 50 deg. Cent., $B=1$, and at 100 deg. Cent., $B=2$.

The above figures appear to suggest that, in fact, the material is only slightly anisotropic, this anisotropy where occurring being of a type indicated by the relations :

$$\varepsilon_1\propto[(\sigma_1-\sigma_3)-(\sigma_2-\sigma_1)]$$
$$\varepsilon_2\propto[B(\sigma_2-\sigma_3)-(\sigma_1-\sigma_3)]$$
$$\varepsilon_3\propto[(\sigma_3-\sigma_1)-B(\sigma_2-\sigma_1)]$$

It is to be noted that this type of anisotropy occurred for this material at 20 deg. Cent. under creep conditions. In that case, however, the degree of anisotropy was very much more marked, B attaining values as high as 15. It seems evident that the development of such anisotropy is favoured by relatively low rates of strain.

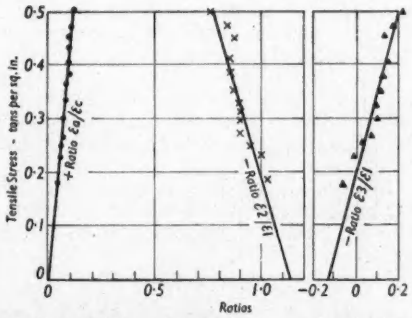


Fig. 31—Variation of Ratios $\varepsilon_a/\varepsilon_1$, $\varepsilon_2/\varepsilon_1$, $\varepsilon_3/\varepsilon_1$, with Stress Ratio $t/s=0\cdot2$, 150 deg. Cent.

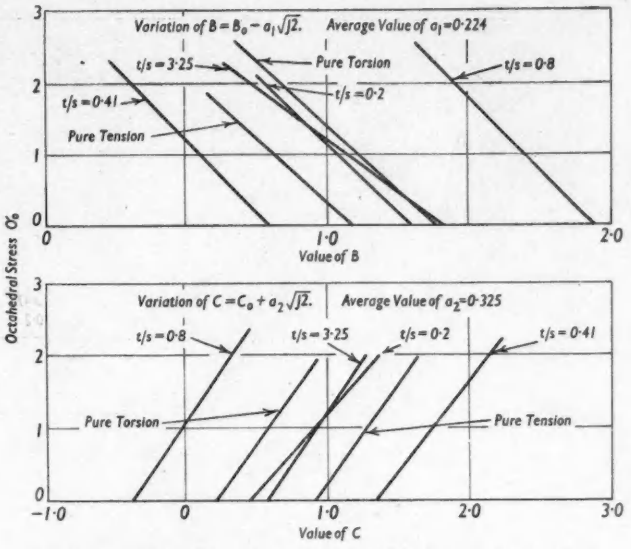


Fig. 32—Variation of Functions B and C with Stress at 150 deg. Cent.

It is possible that the range of values of B may to some degree be due to variations as between test piece material, and divergence from a true criterion rate of stressing of the material. In any case, the degree of anisotropy is small, and does not affect the major principal strains which are precisely as under conditions of isotropy.

In Figs. 33, 35 and 36 the log σ_0—log ε_0 for the three temperatures 20 deg., 50 deg. and 100 deg. Cent. are shown ; it is evident that the experimental points conform well to a linear log-log relation. In Fig. 33 the several lines correspond with stress systems of varying values of B. It is evident that the slight anisotropy does not result in very much displacement of the characteristic curve.

In all three cases the general equation is of the type :

$$\varepsilon_1=A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_1-\sigma_2)-(\sigma_3-\sigma_1)]$$
$$\varepsilon_2=A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [B(\sigma_2-\sigma_3)-(\sigma_1-\sigma_2)]$$
$$\varepsilon_3=A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_3-\sigma_1)-B(\sigma_2-\sigma_3)]$$

where n has the values 1·24, 1·14 and 1·8 respectively at 20 deg., 50 deg. and 100 deg. Cent., and A the corresponding values $3\cdot65\times10^{-6}$, $6\cdot8\times10^{-6}$, and $1\cdot42\times10^{-6}$, B being as quoted in the preceding paragraph.

Turning now to the temperature 150 deg. Cent. and considering the variation of ratios $\varepsilon_a/\varepsilon_c$, $\varepsilon_2/\varepsilon_1$ and $\varepsilon_3/\varepsilon_1$, as indicated in Figs. 28–31, it is to be noted that here these ratios do not assume steady values at stresses above the lower range. Instead, to a good approximation, the values increase or decrease linearly as the stress is raised. Evidently, therefore, if a system of anisotropy of the general type,

$$\varepsilon_1\propto[B(\sigma_1-\sigma_2)-C(\sigma_3-\sigma_1)],\ \&c.,$$

holds in this case, then the variables B, C and A must depend linearly upon stress.

Comparison of the experimental ratios indicated that, in fact, the equations were of the type

$$\varepsilon_1\propto[B(\sigma_1-\sigma_2)-C(\sigma_3-\sigma_1)]$$
$$\varepsilon_2\propto[(\sigma_2-\sigma_3)-B(\sigma_1-\sigma_2)]$$
$$\varepsilon_3\propto[C(\sigma_3-\sigma_1)-(\sigma_2-\sigma_3)$$

where

$$B(\sigma_1-\sigma_2)-C(\sigma_3-\sigma_1)\equiv(\sigma_1-\sigma_2)-(\sigma_3-\sigma_1),$$

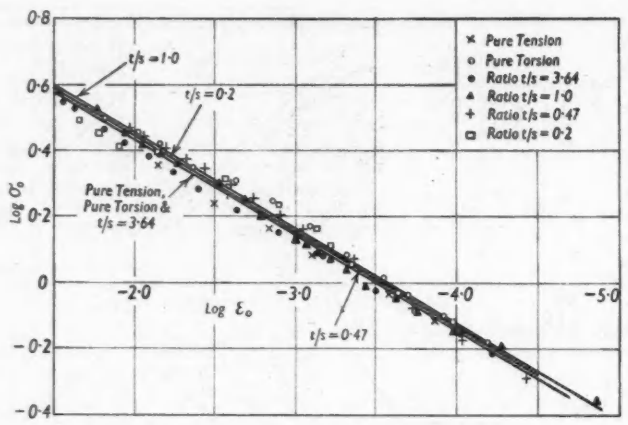
and B and C are of the form,

$$B=Bo-a_1\sqrt{J_2},\ C=Co+a_2\sqrt{J_2},$$

where

$\sqrt{J_2}$ is the second stress invariant.

a_1 and a_2 are virtually constant at all stress systems having average values $a_1=0\cdot224$, and

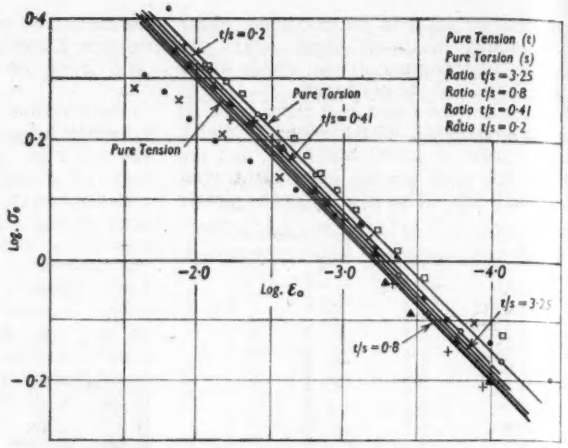


The lines shown in the diagram correspond with the equations:

$$\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_1-\sigma_2)-(\sigma_2-\sigma_1)]$$
$$\varepsilon_2 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [B(\sigma_2-\sigma_3)-(\sigma_1-\sigma_2)]$$
$$\varepsilon_3 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_3-\sigma_1)-B(\sigma_2-\sigma_3)]$$

where $n=1\cdot24$, $A=3\cdot65\times10^{-6}$, and B has the following values :— Pure tension $B=1$, pure torsion $B=1$, t/s 0·47 $B=0\cdot7$, t/s 1·0 $B=2\cdot2$, t/s 3·64 $B=0\cdot7$, and t/s 0·2 $B=0\cdot8$.

Fig. 33—Relations Log σ_o with Log ε_o at 20 deg. Cent. and Various Stress Systems



The lines shown in the diagram correspond with the equations":

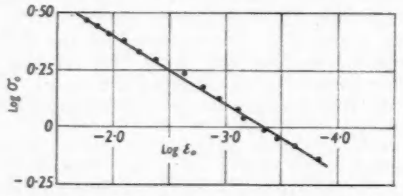
$$\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [B(\sigma_1-\sigma_2)-C(\sigma_2-\sigma_1)$$
$$\varepsilon_2 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_2-\sigma_3)-B(\sigma_1-\sigma_2)]$$
$$\varepsilon_3 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [C(\sigma_2-\sigma_1)-(\sigma_2-\sigma_3)]$$

where $n=1\cdot5$, $A=3\cdot5\times10^{-6}$, and $B=B_o-a_1\sqrt{J_2}$, $C=C_o+a_2\sqrt{J_2}$ B_o, C_o, a_1, a_2 are numerical constants, J_2 is the second stress invariant.

Fig. 34—Relations Log σ_o with Log ε_o at 150 deg. Cent. and Various Stress Systems

$a_2=0\cdot325$, and Bo and Co vary with the stress system between the respective values 0·8 to 1·95, with average 1·33, and —0·34 to 1·34 with average 0·52.

This variation of B and C is shown in Fig. 32, and it is evident that the linearity of the stress dependence is well established, as is also the virtual constancy of a_1 and a_2. The variations of Bo and Co are obviously not such that the variation with stress system can be dismissed as entirely trivial, but, on the other hand, it is not very heavily marked.



The line shown in the diagram corresponds in principal stress relations of type :

$$\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_1-\sigma_2)-(\sigma_3-\sigma_1)]$$
$$\varepsilon_2 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_2-\sigma_3)-(\sigma_1-\sigma_2)]$$
$$\varepsilon_3 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_3-\sigma_1)-(\sigma_2-\sigma_3)]$$

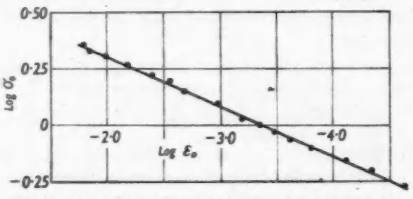
where $n=1\cdot14$, $A=6\cdot8\times10^{-6}$.

Fig. 35—Relation Log σ_o with Log ε_o at 50 deg. Cent and Ratio $t/s=1\cdot13$

In Fig. 34 the relation log σ_0—log ε_0 is plotted for the temperature 150 deg. Cent. The lines shown correspond to the equations :

$$\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [B(\sigma_1-\sigma_2)-C(\sigma_2-\sigma_3)]$$
$$\varepsilon_2 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_2-\sigma_3)-B(\sigma_1-\sigma_2)]$$
$$\varepsilon_3 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [C(\sigma_3-\sigma_1)-(\sigma_2-\sigma_3)],$$

where $n=1\cdot5$, $A=3\cdot5\times10^{-6}$, and B and C vary as indicated in Fig. 32. The several lines shown correspond to the various stress systems. It is to be noted that in this general system of anisotropy the pure tension and pure torsion tests give rise to anisotropy, in contrast to the behaviour at 20 deg., 50 deg. and 100 deg. Cent., where the plastic strain under these two systems was isotropic.



The line shown in the diagram corresponds to principal stress relations of type :

$$\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_1-\sigma_2)-(\sigma_2-\sigma_3)]$$
$$\varepsilon_2 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [B(\sigma_2-\sigma_3)-(\sigma_1-\sigma_2)]$$
$$\varepsilon_3 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_3-\sigma_1)-B(\sigma_2-\sigma_3)]$$

where $n=1\cdot8$, $B=2$, and $A=1\cdot42\times10^{-6}$.

Fig. 36—Relation Log σ_o with Log ε_o at 100 deg. Cent. and Ratio $t/s=1\cdot14$

The values of B and C shown in Fig. 32, and corresponding to tension and torsion, are, of course, not obtained from measurements in experiment, but are derived from the general anisotropic equations by working backwards to the tensile and torsion test values. In Fig. 34 it will be noted that some divergence from the general lie of the experimental points is shown in the case of the higher stresses under pure tension, and the high tension ratio $t/s=3\cdot25$. This divergence is probably fictional, since the disposition of the furnace in these two tests at 150 deg. Cent. appears to have been such as to retard the degree of plastic strain taking place at the higher stresses. Steps are to be taken to rectify this matter; meanwhile the divergence of these few points should not be taken too seriously. As regards the physical significance of the above equations, it appears likely that since C increases with stress and B diminishes, the tendency is for the wall thickness plastic strain to increase relatively to diametral plastic strain as the stress increases, and this may possibly be explained by the basal planes of the hexagonal crystal lattices rotating gradually to a position in the plane of wall thickness, when easiest slip would occur in these planes, leading to an increased proportion of wall thickness plastic strain.

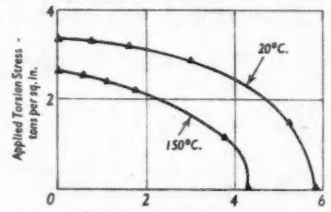


Fig. 37—Relation Between Applied Tensile Stress and Applied Torsion Stress to Produce a Specific Octahedral Plastic Strain of 1 per Cent.

In Figs. 37 and 38 data useful in design are presented, similar data is readily obtainable from other experimental results in this paper.

Conclusions

(1) At 20 deg., 50 deg. and 100 deg. Cent. the material conforms to stress/plastic strain equations of the general type :

$$\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_1-\sigma_2)-(\sigma_2-\sigma_1)]$$
$$\varepsilon_2 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [B(\sigma_2-\sigma_3)-(\sigma_1-\sigma_2)]$$
$$\varepsilon_3 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_3-\sigma_1)-B(\sigma_2-\sigma_3)]$$

where B varies with the stress system.

The equations correspond to a state of anisotropy. The anisotropy, however, seems to be of a largely incipient nature, the average value of B being 1·1.

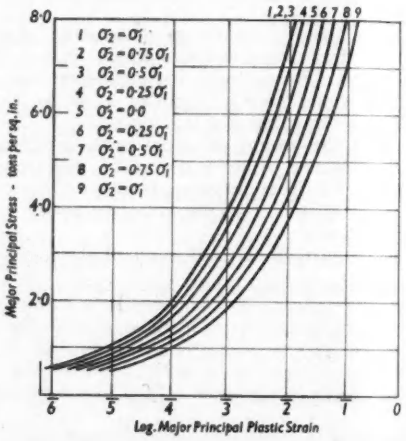

1,2,3 4 5 6 7 8 9
1 σ2 = σ1
2 σ2 = 0·75 σ1
3 σ2 = 0·5 σ1
4 σ2 = 0·25 σ1
5 σ2 = 0·0
6 σ2 = 0·25 σ1
7 σ2 = 0·5 σ1
8 σ2 = 0·75 σ1
9 σ2 = σ1
Major Principal Stress - tons per sq. in.
Log. Major Principal Plastic Strain

Fig. 38—Major Principal Stress—Major Principal Plastic Strain Relations for Various Values of the Minor Principal Stress, and Based on the Equations $\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_1-\sigma_2)-(\sigma_2-\sigma_1)]$, where $n=1\cdot24$, $A=3\cdot56\times10^{-6}$ at 20 deg. Cent.

The major principal strain is just as under isotropic conditions.

(2) At 150 deg. Cent. the material conforms to equations of the general type :

$$\varepsilon_1 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [B(\sigma_1-\sigma_2)-C(\sigma_2-\sigma_3)]$$
$$\varepsilon_2 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [(\sigma_2-\sigma_3)-B(\sigma_1-\sigma_2)]$$
$$\varepsilon_3 = A[\Sigma(\sigma_1-\sigma_2)^2]^n\ [C(\sigma_3-\sigma_1)-(\sigma_2-\sigma_3)]$$

where

$$B(\sigma_1-\sigma_3)-C(\sigma_3-\sigma_1)\equiv(\sigma_1-\sigma_2)-(\sigma_2-\sigma_1),$$

and

$$B=Bo-a_1\sqrt{J_2},\quad C=Co+a_2\sqrt{J_2},$$

$\sqrt{J_2}$ being the second stress invariant, a_1 and a_2 general constants, and Bo and Co constants depending on the stress system concerned.

The major principal strain is just as under conditions of isotropy, and the tendency is for an increasing proportion of secondary

creep to take place in the direction of wall thickness as stress increases.

ACKNOWLEDGMENTS

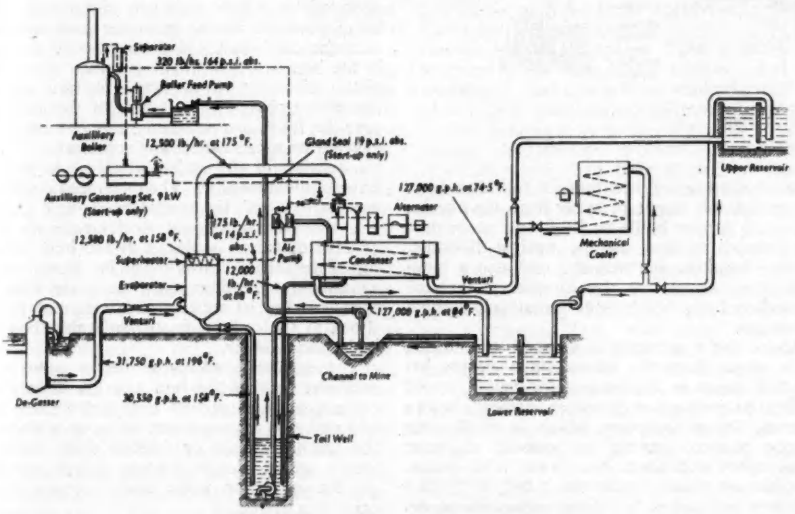
The work described above was carried out in the High Temperature Mechanical Properties Section of the National Physical Laboratory as part of the programme of the Mechanical Engineering Research Board, and this paper is published by permission of the Director of the National Physical Laboratory and the Director of the Mechanical Engineering Research Organisation of the Department of Scientific and Industrial Research.

Power from Hot Water

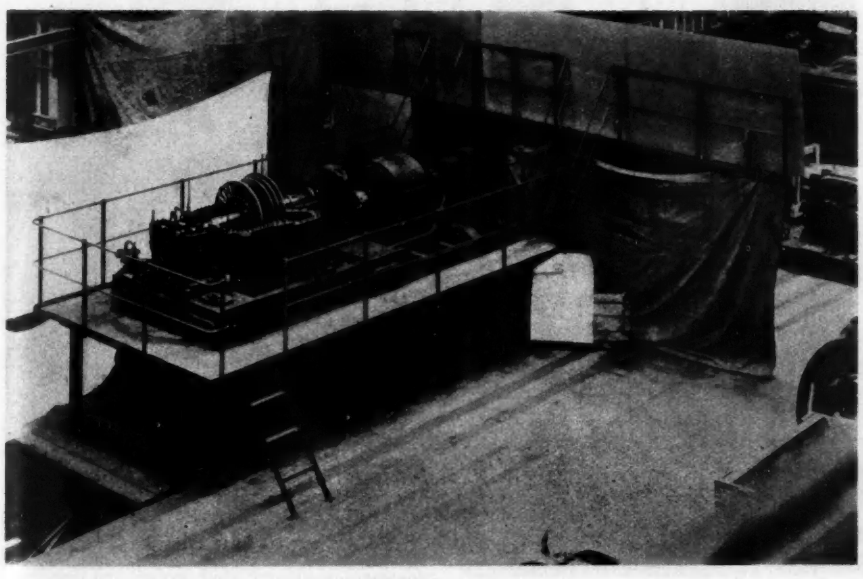
Among the natural sources of power are hot water springs, and to generate the electrical power required for working a tin mine situated in the Belgian Congo it was decided to utilise hot water from a local spring in conjunction with cold water from natural drainage to produce the necessary power. A small turbine generating set making use of these natural resources has been designed and built by Belliss and Morcom, Ltd., to produce 220kW at normal load.

THE Societe d'Exploitation et de Recherches Minieres au Katanga is opening a tin mine in the heart of the Belgian Congo, the site being some 100 miles from the nearest settlement in mountainous country at a height of 2500ft above sea level. Due to the remote position of the mine the production of power, using ordinary fuel, would be very expensive owing to the high transport charges involved and the company decided to investigate the possibilities of utilising hot water from a local spring in conjunction with cold water obtained from local drainage. At a given datum overflow level the quantity of hot water proved to be approximately 31,750 gallons per hour at 196 deg. Fah. and further investigation showed that, by lowering the natural level, 55,000 gallons per hour at 200 deg. Fah. could be made available. For cold water supplies there is a reservoir 600ft distant from the hot spring and 20ft higher, from which, for most of the year, 127,000 gallons per hour at 74·5 deg. Fah. are available.

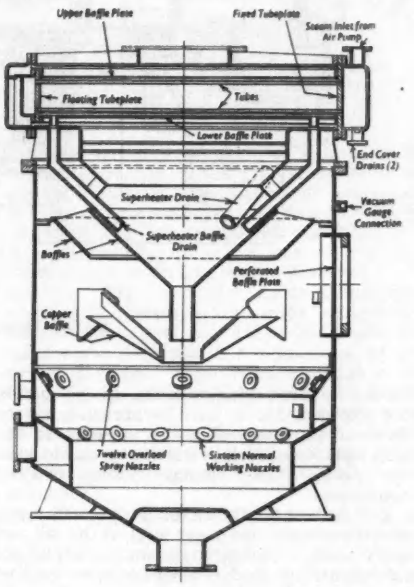
These figures were submitted to Belliss and Morcom, Ltd., of Birmingham, as a basis for designing a plant to produce the necessary power and the company decided to build a turbine generator to produce 220kW as a normal load with the normal hot water flow and an overload of 275kW with the increased hot water flow. It is intended to operate the mine twenty-four hours per day, but the load fluctuates, an average of 200kW being required during the day shift, while during the remaining sixteen hours the average is 150kW. To ensure a continuous supply of cold water a large storage reservoir is planned at a lower level than the power station, and during the sixteen hours when surplus power is available the water will be pumped back to the upper reservoir by means of three pumps which can be used individually or in unison. The areas of the lower and upper reservoirs are 73,000 square feet and 24,500 square feet respectively. In the dry season the upper reservoir may fail and to cover for this a mechanical water cooler is to be installed at a higher level than the power station so that the water circulated by the three pumps can gravitate back to the plant.



Flow Diagram of Hot Water Power System



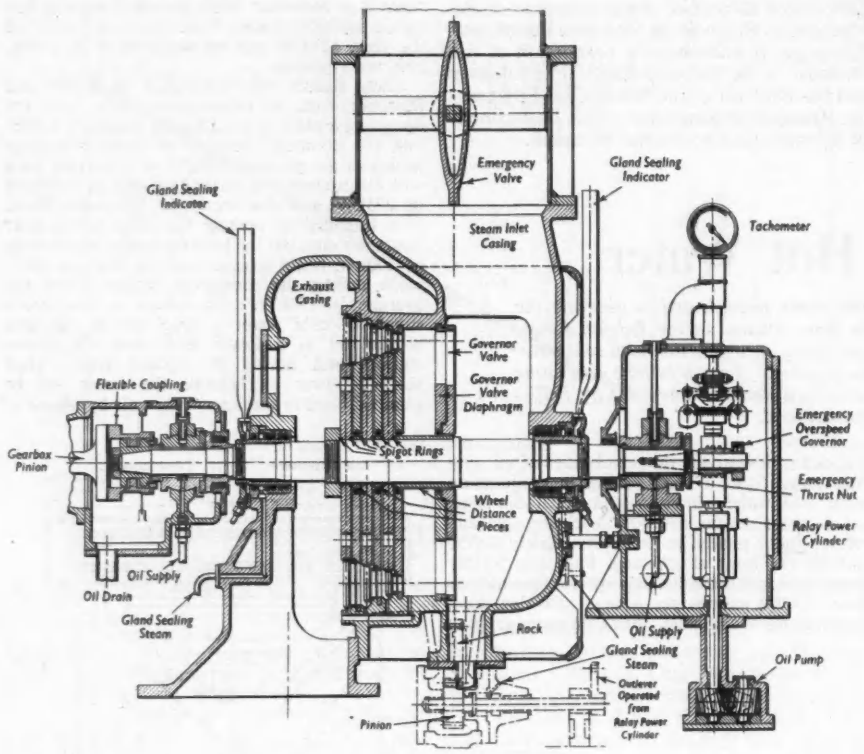
Turbine with Cover Removed



Section Through Evaporator

With the temperature of the hot water inlet fixed and that of the exhaust steam governed by the outlet cold water temperature there is an optimum value of the temperature drop of the hot water to produce steam, and of the heat drop through the turbine to produce power. At 220kW load the temperature of steam generation for this optimum value is 158 deg. Fah., corresponding to 4·5 lb per square inch absolute, the pressure at the turbine being 4 lb per square inch absolute after allowing for a drop of 0·25 lb per square inch between evaporator and turbine and the same drop across the turbine governor valve. The vacuum at the turbine exhaust is 28·64in (barometer 30in) with cold water at 74·5 deg. Fah.

Steam jet air pumps were adopted in preference to water jet air pumps, since wood fuel is available in the neighbourhood and the heat from the second stage steam from the pumps could be reclaimed by incorporating a superheater to improve steam consumption and reduce the possibility of turbine blade erosion. Because the maintenance of a high vacuum is essential, potential sources of air leak must be reduced and barometric legs are used for the removal of hot water from the evaporator and the condensate, a well being sunk for the purpose. Two vertical tail well pumps, drowned in the well and



Section Through Steam Turbine

having extended spindles to the driving motors, are provided, one to cater for normal hot water flow and the other, of smaller capacity, to deal with light loads, such as starting up and to assist the normal duty pump during overload conditions.

For starting up, the motor of the small pump, which maintains the water level in the tail well low enough to enable the turbine to start up and run against light load, is connected to an auxiliary generator. Manual change-over is made to the main turbo-alternator when the turbine is up to speed, and pump controls then become automatic. The small pump continues to operate and, at a predetermined level, the normal duty pump cuts in, both pumps operating in parallel. The well level rapidly drops to a point where the small pump cuts out and, should the water reach the low level limit, a further electrode will cut out the normal duty pump until the level rises 4·5ft. Any rise in level, occasioned by overload conditions, will bring in the small duty pump to assist the normal duty unit.

Description of Plant

The power station, the main units of which are indicated in the flow diagram on page 719, consists of a turbine driving an alternator through reduction gearing, all mounted on a rectangular condenser with the air pump on an adjacent wall. In a pit at the end of the turbo-generator unit is the evaporator, which is mounted with its inlet at a distance of 1m below the natural overflow level of the hot spring. The barometric well is placed alongside the main building next to the evaporator and the small boiler together with the pilot engine are in a lean-to annexe, while the three cold circulating water pumps are installed in a building over an extension to the lower reservoir.

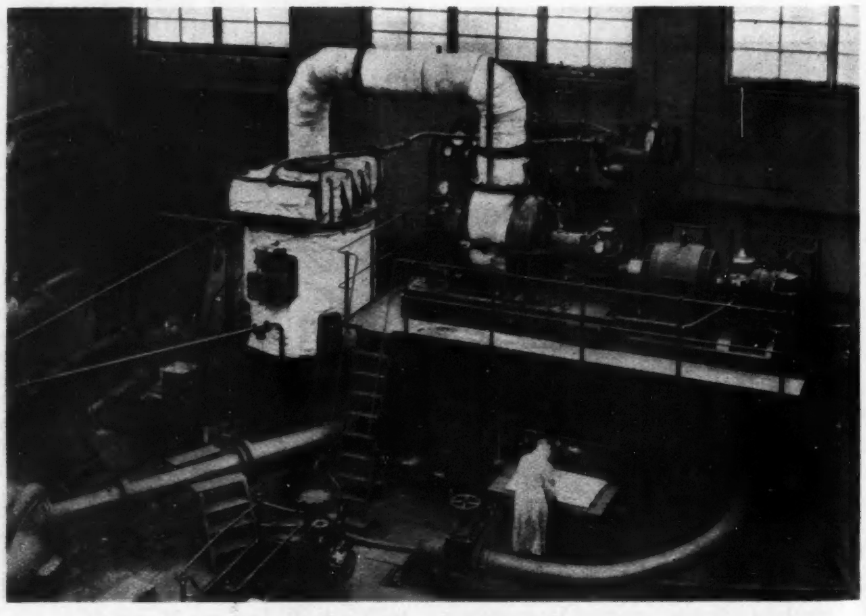
A drawing on page 719, shows the sectional arrangement of the fabricated steel evaporator which has two rows of stainless steel nozzles, the upper row being used for starting and also during overload periods, and the lower row for the normal hot water flow of 31,750 gallons per hour. Hand control regulates the flow to the lower row of nozzles while the supply to the upper row is controlled automatically by an "Arca" valve actuated by the pressure drop across the governor valve at the turbine. The valve opens to admit additional water to the upper nozzles when the pressure drop falls below that for full load duty. To restrict the height of spray from the nozzles a conical copper baffle is fitted and to protect the evaporator and turbine against flooding, vacuum breakers are provided and also a high-water-level alarm, by the Drayton Regulator Company, Ltd., which gives visual and audible indication.

Above the evaporator is a superheater which takes steam from the second-stage ejector jet. Flashed steam in the evaporator passes round baffles, to reduce the moisture content, before entering the superheater, which is of floating header pattern, having ¾in outside diameter brass tubes expanded into brass tube plates. The heating steam, inside the tubes, is divided into two and passes four times across the superheater, the condensate passing to waste. At the normal flow of 31,750 gallons per hour at 196 deg. Fah., 12,000 lb of steam at 4·5 lb per square inch absolute is generated, and with the rate of flow increased to 55,500 gallons per hour at 200 deg. Fah. the amount of steam is 15,200 lb per hour, both quantities being obtained when exhausting to a vacuum of 28·64in (barometer 30in).

It is essential that heat loss by radiation is reduced to minimum and to that end the piping carrying the hot water from the hot spring to the degasser and from the degasser to the evaporator, the evaporator itself and the steam pipe from the evaporator to the turbine are all lagged with asbestos mattresses manufactured by the Darlington Engineering Company, Ltd.

The turbine, which can be seen in our line drawing and photograph, is designed to run at 4500 r.p.m. and to drive a Lancashire Dynamo and Crypto alternator at 1500 r.p.m. through reduction gears made by David Brown and Sons (Huddersfield), Ltd. Due to the low temperature cast iron was adopted for the turbine casings and design conditions indicated a 21in diameter inlet system and an exhaust equivalent to 36in diameter. For the turbine it was decided to use three 28in nominal impulse stages having manganese-bronze blades machined from stampings and fixed blading made from rolled brass strip. The size of the inlet system caused the standard governor valve to be replaced by one of gate design, which is of cast bronze and operated by a steel rack and pinion, the pinion being powered by the governor gear using the manufacturer's standard governor box. Enclosed in the box is a centrifugal governor operating a piston oil relay valve, which in turn operates the power piston. The whole of the governing gear is fully compensating. Speed control is effected by a handwheel and screw which adjusts the tension in the spring attached to the ring lever of the governor. The overspeed emergency governor is of the unbalanced ring pattern, and the fabricated mild steel emergency valve of 21in diameter is placed in the inlet pipe on top of the turbine. It is closed by a dead weight, actuated by the emergency governor when the speed reaches 10 per cent above normal, and the shock at the end of its stroke is absorbed by a hydraulic cylinder.

The system operates at below atmospheric pressure, so that the h.p. and l.p. glands must exclude air and carbon ring glands have been adopted, the sealing steam being provided from the engine exhaust or directly from the boiler. Steam sealed Corliss pattern glands are fitted on the governor valve and emergency valve operating shafts.



Turbo-Generator on Test

The main oil pump, which is direct driven from the bottom end of the governor spindle, supplies oil, all of which passes through a Serck cooler, at 40 lb per square inch to the turbine and at 8 lb to 10 lb per square inch to the gearbox and alternator bearings, while the oil operating the governor is uncooled for greater sensitivity and taken direct from the pump.

A Belliss and Morcom designed flexible coupling transmits power from the turbine to the gearbox pinion by means of a series of flat steel springs. The gearbox bearings are designed to carry part of the weight of the alternator armature, and the alternator has a single outboard bearing and a solid coupling at the gearbox.

It was anticipated that a burst of steam would be necessary to overcome static friction; however, in shop trials the starting of the turbine proved to be simple using the following procedure. By means of the second stage ejector a moderate vacuum was created in the main condenser and, with the governor valve wide open and the emergency valve shut, the designed clearance around the emergency valve was sufficient to transmit the vacuum raised in the condenser to the evaporator. Hot water was admitted to the evaporator and steam generated, the pressure rising above that obtaining in the turbine steam chest. Following the partial opening of the emergency valve the pressure in the evaporator fell to provide the necessary conditions for continuous steam generation, thus starting the turbine. When the turbine reached full speed the governor gear came into action and the emergency valve was then set in the full open position for overspeed emergency operation.

The maintenance of a high vacuum at the turbine exhaust called for an unusually large condenser; this is of Belliss and Morcom "Compact" design and of welded steel construction incorporating the turbine bed-plate. It is of rectangular section; the steam enters at the top in the centre over the whole length, the air and non-condensable gases are drawn upwards on both sides, and the condensate flows from the bottom down the barometric leg. Cooling water enters by two inlets, the coldest water passing through the air removal sections and passing three times through the condenser before discharging in one outlet from the centre portion. The brass condenser tubes of ¾in outside diameter and 1121 in number, are secured by brass ferrules and asbestos taped packings to the brass tube plates spaced 12ft 6in apart. The internal tube support plates and securing pins are also in brass, while the water boxes and end covers are cast iron.

The two-stage steam jet air pump has stainless steel steam jets, bronze throats and steel strainers above the jets. The first stage steam is passed through a small tubular condenser, the condensed steam passing through a balance pipe into the main condenser. Second stage steam, as already mentioned, is carried to the evaporator superheater where it is condensed at atmospheric pressure.

The tail well pumps by Holden and Brooke, Ltd., are driven by motors supplied by Lancashire Dynamo and Crypto, Ltd., and the automatic control gear is actuated by "No-float" equipment produced by Evershed and Vignoles, Ltd. The normal duty pump is driven by a 9 b.h.p. motor and delivers 570 gallons per minute against a 29ft head when running at 1450 r.p.m. Of double suction split casing design, the pump has a vertical drive and is suspended at a depth of 36ft 4¾in by mild steel fabricated support piping, which serves as a delivery main for discharge of the water. The small pump, driven by a 5 b.h.p. motor, has a capacity of 310 gallons per minute against a 22·5ft head when running at 1450 r.p.m. It is of single inlet end suction pattern and is suspended at a depth of 35ft, but in this instance the delivery and support pipes are separate. Both pumps have a cast iron volute casing having renewable phosphor-bronze neck rings, a gunmetal impeller and a fabricated mild steel support plate and motor stool. The weight of the carbon steel shaft and the impeller is carried on a Skefko self-aligning double-row ball bearing and there are intermediate steady bearings, manufactured by Small and Parkes, Ltd., running on renewable phosphor-bronze sleeves.

The vertical multi-cross-tube auxiliary boiler, made by the Cradley Boiler Company, Ltd., has a working pressure of 150 lb per square inch and a normal evaporation of 600 lb with a maximum of 700 lb per hour when using dry soft wood logs as fuel. Coal or refuse can be burnt. The direct-driven horizontal duplex boiler feed pump and the feed tank are arranged alongside the boiler. An analysis of the hot spring water showed that it contains no acidity and very little hardness, so that it is used for boiler feed, and a small vertical spindle pump installed over the hot water discharge channel delivers to the boiler feed tank. Taking steam at 145 lb per square inch gauge is a Belliss and Morcom tandem compound single-crank steam engine driving a 9kW, 220V, three-phase, 50-cycle alternator with belt-driven exciter, at 750 r.p.m.

Our photograph shows the plant undergoing shop trials, which presented considerable difficulties, particularly the problem of simulating the conditions obtaining on site, including the production of hot water at the required temperature and the cold water circulating arrangements to simulate the heat transfer conditions. Lack of height prevented the provision of a tail well and the hot water was pumped out and recirculated to the tank by means of a standard circulating water pump provided with special vapour pipes into the inlets of the impeller. Despite difficulties, the tests were carried out and the designed performance was established.

Diesel - Electric Locomotives for Ceylon

Twenty-five 1000 h.p. diesel-electric locomotives are being built for the Ceylon Government Railways by the Brush group of companies in the new locomotive shop at the Loughborough works. These 87-ton locomotives are designed for a maximum speed of 55 m.p.h., and have a continuous tractive effort of 24,600 lb at just under 12 m.p.h.

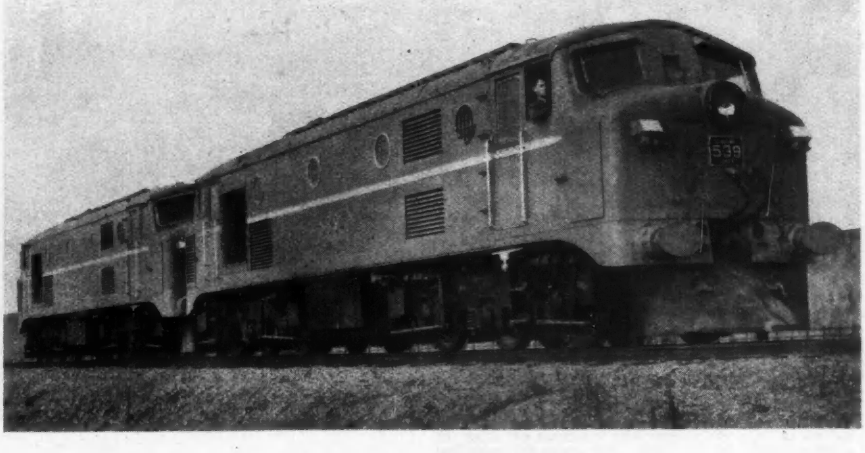
EARLY in 1950, an order for twenty-five 1000-h.p. diesel-electric locomotives for main-line service on the Ceylon Government Railways, was placed with the Brush Electrical Engineering Company, Ltd., of Loughborough, by the Crown Agents for the Colonies. The first of these locomotives is now being shipped, and it is anticipated that one will be ready for shipment each month until the completion of the order. It is of interest to note that until this order was placed, the traction products of the Brush-A.B.O.E. group had been limited to shunting locomotives of up to 500 h.p., and for the design and manufacture of the new locomotives the resources of four companies of the group were drawn upon. For the actual design and erection of the locomotives, Brush-Bagnall Traction, Ltd., was made responsible, the electrical equipment being supplied by the Brush Electrical Engineering Company, Ltd., the diesel engines by Mirrlees, Bickerton and Day, Ltd., and the mechanical parts by W. G. Bagnall, Ltd.

The leading particulars of the new A1A-A1A locomotives, two of which can be seen in one of the photographs we reproduce, are as follows :—

Weight	87 tons
Gauge	5ft 6in
Maximum height	13ft 3½in
Maximum width	10ft 3½in
Length over buffers	50ft 9in
Bogie wheelbase	10ft 6in
Bogie centres	27ft 0in
Minimum curve negotiable	5 chains
Capacity of fuel tank : main	775 gallons
service	75 gallons
Wheel diameter : motored	3ft 7in
carrier	3ft 0in
Maximum speed	55 m.p.h.
Starting tractive effort (26 per cent adhesion)	33,700 lb
Tractive effort (one hour rating)	30,000 lb at 9·2 m.p.h.
Tractive effort (continuous)	24,600 lb at 11·7 m.p.h.
Estimated range with full fuel tanks	750 miles

One of our illustrations shows locomotives in course of erection in the Loughborough shop, and in it there can be seen bogie assemblies at the side of a superstructure deck member in its initial assembly stage, with superstructures in an advanced stage at the rear. The underframe is built up on four main, rolled steel, "I"-sections. The two outer frame longitudinal members terminate at the bogie cross-centre members, to which they are welded; and the inner main longitudinals are extended to the end of the frame, where they are welded to the fabricated drag box. Cross members riveted to the main longitudinals at various points along the underframe carry channel-section solebars. The unbroken steel plate deck member of the superstructure covers the complete underframe structure.

The bogies have welded box side frames joined by a heavy fabricated steel centre transom and two channel members forming headstocks. Each of the bogie centre bolsters, which carry the weight of the locomotive, rests on eight nests of coil springs carried by two spring planks, one on each side of the centre carrier axle. These spring planks are, in turn, suspended by swing links from the bogie frames. The leaf springs of the axles are mounted within the hollow side frames of the bogies, whilst the coil springs are arranged below the frames. The bogies are fitted throughout with roller bearing axleboxes mounted in replaceable manganese steel horn guides. Each of the driving axles is fitted with a tube for the support of the traction motor, which is nose-suspended by a flexible link from the centre transom. Drive from the motor to the axle is through single-reduction gearing—a pinion on the armature shaft meshing



1000 H.P. Diesel-Electric Locomotives

with a resilient gearwheel on the axle.

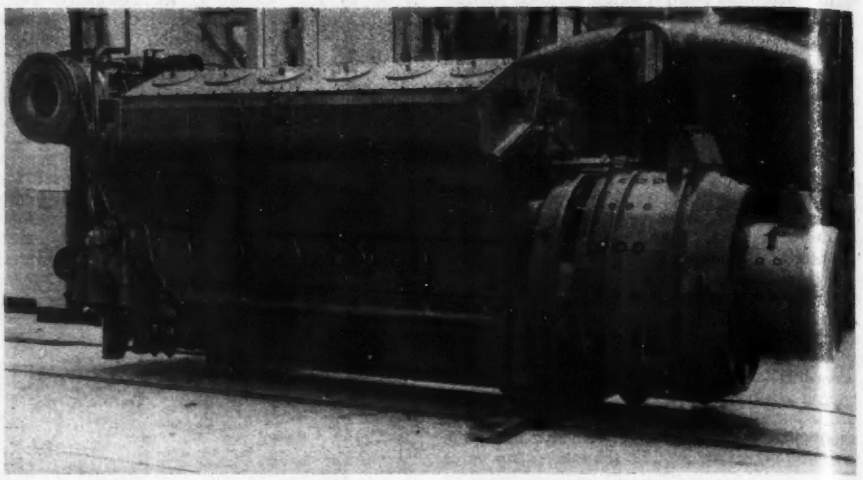
A large driving cab at each end of the locomotive is partitioned off by a bulkhead from the power unit, auxiliary equipment and control gear arranged in the main body. A partition separates the engine from the generator and control equipment, and clear unobstructed walkways are provided along both sides of the compartments. The compact arrangement of the power unit and the wide loading gauge of the railways in Ceylon have made it possible to give full and free access to all parts of the equipment from walkways of reasonably comfortable width and height. When engine overhaul becomes necessary, it will be possible, with the room available, to withdraw easily the pistons and connecting-rods from the sides of the crankcase.

In the short, streamlined nose-end compartment in front of each driving cab, is an electrically-driven traction motor blower which supplies the cooling air to the two motors in the bogie beneath. Behind the cab at one end of the locomotive is the main radiator ducting, in which is mounted the radiator fan motor and runner. Cooling air is drawn through large radiator panels built into each side of the locomotive, and after passing through twin branches of the ducting, it is ejected upwards through a grille in the roof.

All the locomotive auxiliaries are electrically-driven except the engine cooling water circulating pump, which is belt driven from the free end of the crankshaft, and the engine lubricating oil pumps, which are gear driven from the crankshaft. The main fuel tank and batteries are slung beneath the locomotive frame between the bogies, and a separate fuel service tank is mounted in the roof.

The locomotives are powered by the vee, twelve-cylinder, turbo-charged, four-stroke oil engines of the Mirrlees, Bickerton and Day new "J.V." series. This engine, under normal temperature and altitude conditions, has a rating of 1254 b.h.p. at 850 r.p.m., and under the climatic conditions in Ceylon, it is designed to develop 1000 h.p. at 850 r.p.m. It has a bore of 9¾in with a stroke of 10½in.

The engine has a fabricated bedplate, which carries the crankshaft bearings, and incorporates the engine sump and lubricating oil supply manifold. The cylinder housing and upper part of the crankcase are also of welded construction and the complete crankcase assembly is rigidly bolted to the bedplate. Wet cylinders are fitted, and each cylinder head has the injector arranged centrally between two exhaust and two inlet valves. Twin camshafts, mounted in the cylinder housing and driven by spur gearing from the end of the crankshaft, operate the valves and fuel pumps through roller-ended push-rods and tappets.



Diesel Engine and Generator Unit

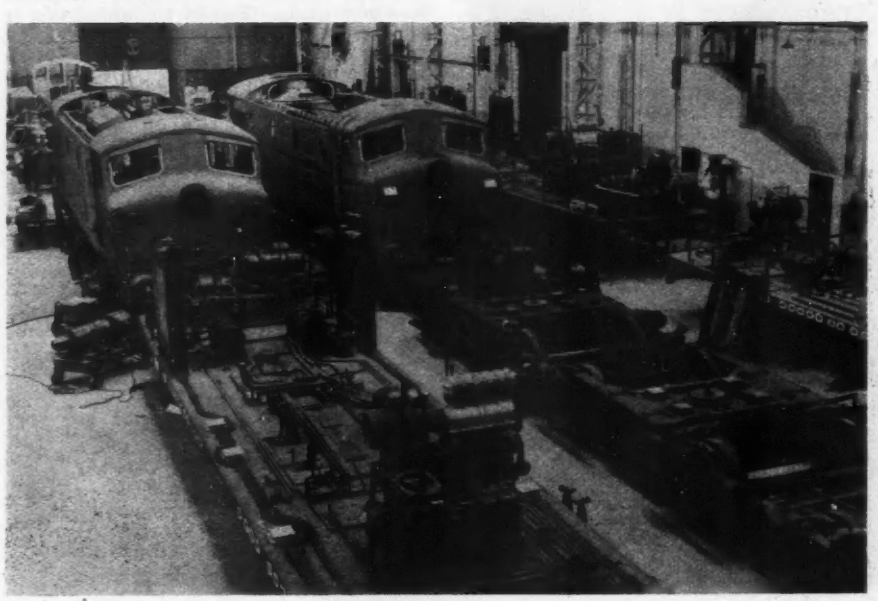
The engine is pressure-lubricated throughout by gear pumps, and a shut-down device is designed to stop the engine automatically should the oil pressure fall below a predetermined point, or the engine speed exceed a certain limit.

The engine and generator, which are bolted together to form a single unit, as shown in one of the illustrations on this page, are mounted on three pedestals carrying "Silentbloc" bushes. Engine starting is effected by motoring the main generator from starting batteries, and starting connections cannot be made until sufficient oil pressure has been built up in the engine by an electrically-driven priming pump.

The main generator has a continuous rating of 652kW, 630V, 1035A, or 652kW, 750V, 870A, at 850 r.p.m. It is directly-coupled to the oil engine and provides power to the four traction motors on the two outer axles of each bogie. These traction motors have a continuous rating of 196 h.p., 315V, 517·5A, and a one-hour rating of 226 h.p., 315V, 610A. They can be connected in series parallel, full parallel, or arranged so that an initial connection in series-parallel is regrouped automatically to full parallel. Control during running of the locomotive is effected by varying the excitation of the main generator and the speed of the oil engine. Current for the field excitation of the main generator, auxiliary machines, battery charging and operation of the control equipment, is supplied from the auxiliary generator mounted on an extension of the main generator shaft. The control equipment is mounted in a dust-proof cubicle in the generator compartment.

Compressed air brakes fitted to the locomotive are provided with air by a Westinghouse compressor, which also supplies air for the control and other auxiliary equipment. Four compressed air brake cylinders are fitted on each bogie and they operate clasp brakes on all wheels. To provide vacuum for the train brakes, twin, four-cylinder, motor-driven Westinghouse exhausters are arranged at one end of the power compartment. The brake in the driver's cab consists of a vacuum valve which operates the train brakes and automatically operates the locomotive brakes through a proportional valve. This valve is designed to ensure that the locomotive air braking is applied in direct proportion to the vacuum braking on the train. A separate brake valve is used for independent braking on the locomotive when required.

The locomotives are arranged for multi-unit operation, and in such cases the units are coupled electrically as well as mechanically, so that they are controlled by a driver in the front cab of the leading locomotive. In the driving cabs the driver and his assistant each have large windows giving a wide unobstructed view forward. The controls are arranged for comfortable operation and the essential instruments are set in a panel in front of the driver. The master controller on the driver's left has a single handle through which he can select the engine starting, forward and reverse positions and all running notches. The brake valve control is on the driver's right and at his feet are two "dead man's" pedals and a sanding pedal. Pneumatically operated windscreen wipers are fitted to the front windows, and a powerful headlamp is fitted into the nose at each end of the locomotives.



Locomotives Being Erected

BRIDGE OVER THE RIVER BURE.—The new main road crossing of the River Bure at Great Yarmouth, between North Quay and Acle New Road, is carried over a Callender-Hamilton bridge of 110ft span. A double carriageway is provided with a road width of 18ft and clear headroom of over 18ft. A footway 5ft wide is carried on cantilevered supports outside one of the main girders. The main bridge steelwork was assembled complete on the shore and moved to a position with the projecting end sufficiently far advanced to enable a barge with supporting scaffolding to be floated in under the next to end panel point where, on a rising tide, the weight of the end of the bridge could be supported. With the tail end of the bridge mounted on rollers, the operation of floating the bridge across the river and landing in on the supporting jacks on the two abutments was carried out in 5½ hours. Completion of the bridge entails the fitting of the side-walk, pressed steel troughing and the concreting of the deck surface to connect with the new road formation work, enabling traffic to use the bridge while the old bridge of tubular construction, which has been in use for many years, can be dismantled. The main bridge steelwork was fabricated by Painter Bros., Ltd., of Hereford, and galvanised in accordance with the normal practice for these bridges. The pressed steel troughing, together with steel kerbs, ballast plates, and abutment steelwork, was supplied by Dorman Long and Co., Ltd., of Middlesbrough. The contract for the erection of the bridge was undertaken by Carter Horseley (Engineers), Ltd., for the County Borough of Great Yarmouth.

Push Button Signalling Control at Ealing Broadway

TO-MORROW London Transport is bringing into service a new form of signalling control at Ealing Broadway, operated from a push-button control desk in a new signal cabin. On the desk, which is illustrated herewith, there are forty-three push buttons, whereby the whole of the signalling for the Ealing Broadway terminal stations of the District and Central Lines is controlled. Each push button is associated with a particular route and when the appropriate button is depressed it operates the points and signals for that route.

An important characteristic of this system is that the push buttons are self-restoring. It follows that the complete operation of signalling a train through a selected route is achieved by the signalman pressing the appropriate button once, after which no further action is required on his part to restore the route. Because of this self-restoring characteristic it has been possible to incorporate, for the first time, a system of preselection, whereby the signalman can press the button for another train movement after he has cleared the signals for a previous movement. Then, immediately the first train has passed through its route, the points will be operated for the second route and the signals cleared without any further effort on the part of the signalman.

The push buttons are made of transparent "Perspex," and, by means of three coloured lights mounted below them which cause them to be illuminated, they act as indicators to the signalman. When the route is at danger the buttons are coloured red and, when a button is pressed to select a route, its colour changes to yellow. When the route is set and the signals are cleared, the colour of the button changes from yellow to green and remains so until the signals have been replaced to danger by the passage of the train, when the button reverts to red. A signal which has been cleared by the pressing of a button may be replaced to danger by pulling the same button. Similarly, a button which has been pressed and has changed to yellow, indicating that the route has been pre-selected, may be pulled to cancel the operation.

The design of the desk is such that the signalman is able to sit in front of it and have all the controls within easy reach of him. A telephone control panel is provided on the left-hand side of the desk and the equipment includes a microphone and loudspeaker with a two-way switch so that, alternatively, an ordinary hand microphone set can be used. Instrument indications and push buttons for the control of train indicators are provided on the right-hand side of the desk. An illuminated diagram located behind the control desk gives the signalman illuminated indications of the conditions of all the track circuits, signals and points in the area under his control.

Each of the forty-three push buttons is embodied in a removable assembly, as shown in one of our illustrations. All the push-button assemblies are interchangeable and the route number and title is inscribed on a removable ebonite plate, which is normally flush with the surface of the desk. As can be seen from the illustration, the lower portion of the push button is in the form of a "Perspex" wedge, which actuates the switch contacts and transmits the "piped light" from any one of the three bulbs below it. When the push-button assembly is in the "home" position the control circuits are completed through a contact-jack.

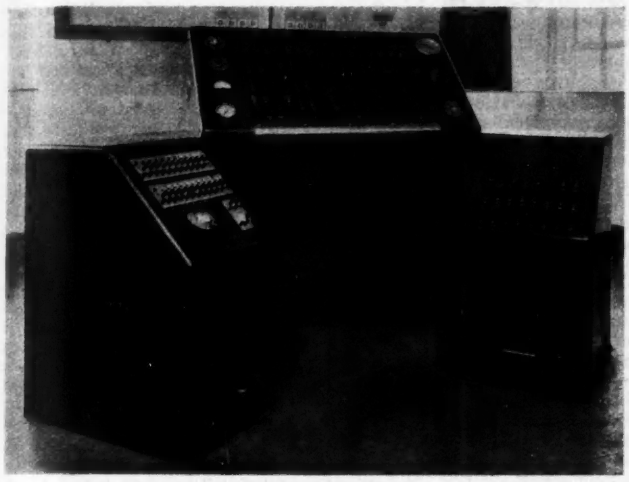
Operation of the push buttons actuates the appropriate signals and points through the medium of an air-operated lever system, the lever frame being installed in the ground floor of the signal cabin, immediately below the control room. The lever frame is of orthodox design, except that each lever is operated by pneumatic pistons, the valves of which are push-button controlled, as described. The levers are electrically and mechanically interlocked. In an emergency, or in the event of an electrical fault, the levers can be operated manually from the ground floor after merely turning a hand cock to shut off the air supply.

Telephone type relays and wiring are used for the circuit link between the push buttons and the air-operated levers. Orthodox practice is embodied in the whole of the signalling and safety circuits, making use of apparatus and cables that conform to the normal signalling standard requirements. One of our illustrations shows a single-element vane relay, which incorporates a recent improvement—an impact detector. This detector is mounted in the lower left-hand corner of the relay casing, and consists of a weight which would be displaced if the apparatus suffered an impact or vibration sufficient to cause mal-operation of this sensitive form of relay. Displacement of the weight gives immediate visual indication that the relay has been subjected to mechanical disturbance.

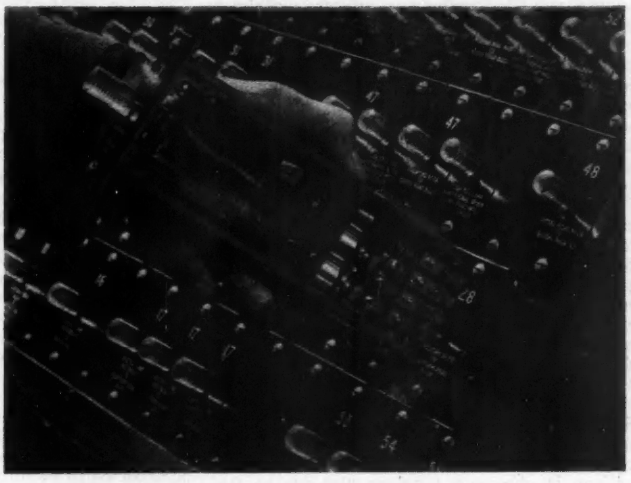
For the signalling circuits the electrical supply is, as usual, at 33⅓ cycles per second. Direct current for the push-button circuits is obtained by metal rectifiers from the 33⅓ c/s supply.

Provision has been made for automatically signalling the Central Line trains into and out of the terminal station if this facility should be required at any time. The installation includes the provision of two-aspect colour light signals with junction indicators for diverging movements, train-stops at all signals used by passenger trains, condenser feed track circuits, and electro-pneumatically operated point equipment. Approximately 200 miles of wire with 25,000 terminations have been used on the installation.

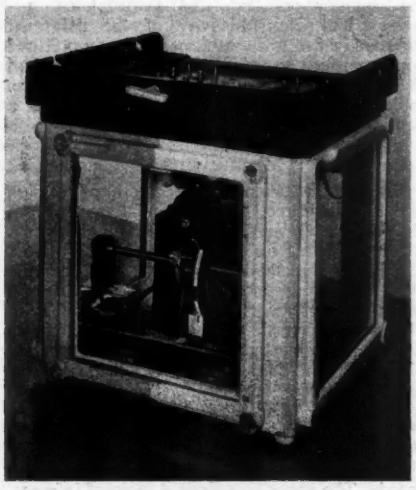
All the work has been carried out by the staff of London Transport under the control of the chief engineer, Mr. P. Croom-Johnson, C.B.E. The system described here was devised by Mr. R. Dell, signal engineer, and was designed, developed and installed by his staff. The push-button control desk and the signalling equipment were manufactured by the Westinghouse Brake and Saxby Signal Company, Ltd.



Push-Button Control Desk



Push-Button Unit Withdrawn from Control Desk



A.C. Single Element Vane Relay

EAST KILBRIDE MECHANICAL ENGINEERING LABORATORY.—In a recent written reply, the Parliamentary Secretary to the Ministry of Works has stated that, in present circumstances, it is not possible to forecast when the building and staffing of the Mechanical Engineering Research Laboratory at East Kilbride, will be completed. Progress has been affected by the need for economies in capital expenditure. Nevertheless, site works, buildings completed and now under construction have entailed an expenditure of about £1,000,000, and it is hoped shortly to start work on a further building costing about £400,000. In addition, temporary accommodation for one section of the laboratory's work has been provided nearby at Thorntonhall. The reply says that the present authorised staff for East Kilbride is 251. It is proposed to make the necessary additions to the staff as further buildings are completed, subject to the requisite funds being available.

Metallurgical Topics

Properties of Metallic Surfaces

A SYMPOSIUM on "Properties of Metallic Surfaces," organised by the Institute of Metals, was held at the Royal Institution on November 19th. Thirteen papers on different aspects of the subject were communicated to the meeting, seven being discussed in the morning and six in the afternoon. They were not introduced individually but were presented in groups by Professor A. H. Cottrell in the morning and by Mr. D. A. Oliver in the afternoon.

The group taken in the morning was concerned mainly with physical and chemical properties. A paper by Professor S. Tolansky contained a review of specialised microscopical techniques used in metallurgy and especially those employed in the study of the topography of surfaces, including the measurement of height and depth features of structures observed under the microscope. Dr. M. T. Simnad, of the Carnegie Institute of Technology, Pittsburgh, U.S.A., gave examples of the use of radioisotopes in the study of metal-surface reactions in solutions. The radioactive tracer technique dates back to 1912, when Hevesy used it in experiments on the separation of radioactive bodies electrochemically and subsequently used radioactive lead isotopes for determining the solubility of sparingly soluble lead salts. The supply of radioisotopes produced by neutron-induced reactions in chain-reacting piles has greatly stimulated research in recent years. In a very complete review of the subject, with 195 references, Dr. Simnad gave a number of examples of the application of tracer technique to the solution of problems related to the behaviour of metals immersed in liquids, and in particular to the formation and properties of surface films. One of the most interesting examples was the use made by Dr. Simnad of radioactive chromate ions from Cr^{51} to study the passivity of metals in chromate solutions and to determine the activity and distribution of chromium on the passivated metals. He was thus able to distinguish between conflicting theories of passivity and to corroborate the conclusions of Hoar and Evans that the passivity of iron in chromate solutions was due to the conversion of the chromate at anodic points into a mixture of ferric and chromic compounds, which seals discontinuities in the oxide film and stops attack on the metal.

Light may be thrown on possible effects of abrasion on metallic surfaces by experiments on other crystalline materials. Drs. Gay and Hirsch described the effect of various abrasive treatments on the surface structure of calcite crystals, as revealed by X-ray and electron diffraction methods. The distortion caused by abrasion produced material misorientated from the main matrix crystal. The extent of the misorientation depended on the coarseness of the abrasive used. With increasing degree of abrasion the range of misorientation increased and the size of the particles on the surface diminished until, after a high polish, the surface was in an apparently amorphous state.

Diffusion Coatings

Messrs. Dovey, Jenkins and Randle contributed a critical review of diffusion coatings which have proved to be valuable in enhancing resistance to wear or to corrosion or to oxidation at high temperatures. A very wide range of commercially valuable diffusion coatings, including hot-dipped coatings, galvanising, calorising, chromising, siliconising, &c., received mention, but attention was mainly directed to processes involving reactions between metal surfaces and a surrounding gaseous atmosphere, including an account of recent developments in the use of controlled atmospheres in the case-hardening of steel.

Mr. H. W. L. Phillips dealt with the nature and properties of the anodic film on aluminium and its alloys. Anodising by one or other of the methods in practical use provides an excellent means of preserving aluminium and most of its alloys from attack, except in severely corrosive conditions. When conditions are very severe, it is desirable to apply a protective paint. The absorptive properties of the anodic film probably provide a better key for paint than any other form of pre-treatment. The mechanical properties of the metal or alloy are not adversely affected except in very thin strip, in which the thickness of the film is comparable with that of the metal.

Chemical Behaviour

The important influence of surface conditions on the chemical behaviour of metals was discussed by Dr. U. R. Evans, who quoted examples of how the surface condition might affect the probability, distribution and rate of attack. Probability of attack may be much higher along a scratch line than elsewhere, and certain inclusions, mainly sulphide particles, may act similarly in the absence of scratches. A good surface was likely to be advantageous ; but when the total attack was fixed by some external factor, e.g. the rate of oxygen supply, the corroded area was likely to be smallest and the intensity of corrosion greatest when the surface was most nearly perfect. The initial velocity of attack might be affected by surface condition, but the influence on velocity was likely to disappear if and when the whole of the surface layer had been removed by corrosion. Dr. Evans was concerned with chemical behaviour, mainly in connection with corrosion, and with the practical effects of corrosive conditions. He stated that surface defects were likely to increase the risk of corrosion fatigue, and also to increase the number of discontinuities in any protective coatings which might be applied. Peening appeared, in some circumstances, to reduce the liability to corrosion-fatigue and stress-corrosion cracking. In certain liquids, however, peened steel suffered corrosion-fatigue more easily than finely ground steel, and in some aircraft alloys there was a risk that surface treatment would lead to the type of intergranular network favourable to stress-corrosion cracking. Electropolishing held out promise of providing a surface which, if not specially resistant to attack, should at least be reproducible, so that inhibitive treatments or protective coatings might be expected to produce consistent results.

High-Frequency Resistance

In the last of this group of papers, Drs. Chambers and Pippard dealt with the effect of method of preparation on the high-frequency surface resistance of metals. The high-frequency behaviour of a metal is determined by the properties of a thin surface layer of the order of a micron in thickness. Observed values of surface resistance might exceed those predicted, either because the surface was rough or because the surface layer had a higher direct-current resistivity than the bulk of the metal. Roughness was the more important factor at room temperature. Electroplated surfaces appeared to be the roughest, followed by machined, drawn, mechanically polished, and electroplated surfaces. The d.c. resistivity of the deformed surface layer of a smooth, mechanically polished copper surface was about 5 per cent greater than that of the bulk metal at room temperature, indicating considerable deformation down to a depth of several microns.

Machinability

The papers taken at the afternoon session had a more direct engineering interest. From the B.S.A. Group Machinability Laboratory, Messrs. Spear, Robinson and Wolfe contributed a study of metal-cutting operations in mild steel, duralumin and 60 : 40 brass. Surface-finish measurements made with the Taylor Hobson Talysurf on machined test-pieces, together with hardness tests and both X-ray and visual examination, were applied to surfaces produced under various machining conditions and by tools of different materials (high-speed steels, sintered carbides and alumina) ground in various ways. The effect of depth of cut, cutting speed and feed, and of cutting fluids was investigated. The paper contained a mass of information, valuable for reference purposes to those interested.

Lubrication and Surface Films

Dr. F. T. Barwell dealt with the effect of lubrication and the nature of the superficial layer in a bearing after prolonged periods of running. He described the various forms of wear. In continuous wear, small particles are removed and carried away by the lubricant without causing any great surface damage. This type of wear is normal during a running-in period. Scuffing, or gross disruption of the mating surfaces, is shown to result from an unstable condition, due to frictional heat, which tends to increase surface irregularity. Pitting, a common cause of failure of ball bearing and gears, is attributed to fatigue of metal below the surface and in the region of maximum shearing stress. Fretting corrosion occurs when two mating surfaces, nominally at rest with respect to one another, are subject to slight vibrational slip. The damage produced is characterised by pitting of the surfaces and the generation of a considerable quantity of finely divided, oxidised debris. Protection afforded by the usual kinds of lubricant may prove to be inadequate when extreme pressures are developed between the sliding surfaces. In such circumstances one of the most successful processes applied to ferrous specimens has been that in which a deep phosphate coating is formed on the surface. Such a coating is strongly bound to the ferrous substrate and its porous structure is valuable when it is used with a lubricant. The effectiveness of a bonded molybdenum sulphide film can be greatly increased when used in conjunction with a phosphate treatment. Phosphating has also proved to be an extremely valuable palliative for fretting corrosion. Attention was drawn to anodising as a method of overcoming the extremely poor bearing characteristics of an aluminium surface. Other methods touched upon were the oxidation of a metal surface by the action of a special "extreme-pressure" additive, the formation of a soap or of an inorganic salt or of a polymerised film on the metal surface.

Closely related to the subject matter of Dr. Barwell's paper was a communication from Drs. Bowden and Tabor, on the influence of surface films on the friction and deformation of surfaces. Interaction between metal surfaces is dependent on the surface films with which they are covered. In the absence of all contaminating films, gross seizure occurs and sliding is impossible. The authors presented results of investigations which showed that the physically adsorbed films were only one or two molecular layers in thickness. The friction and surface damage of inert metals immersed in an electrolyte was often influenced by small changes in the interfacial potential, largely because of the protective properties of electro-deposited gas layers. The oxide film normally present on most metal surfaces could also provide considerable protection, particularly at light loads. At high speeds of sliding, the material, softened or melted by the high temperature generated at regions of contact, was smeared over the surfaces to form a Beilby layer. This layer might offer considerable protection to the underlying metal during sliding. Boundary lubricant films also acted as protective films when they were in the solid state. For effective protection at high temperatures, solid films of high melting point must be used. Films of soft metals, of the plastic polytetrafluoroethylene, of molybdenum sulphide or of other metal sulphides or chlorides were particularly suitable for this purpose. Differences in their characteristic behaviour were pointed out.

Mechanical Properties

The remaining papers dealt with mechanical properties. Professor Andrade's paper on the effect of surface conditions on mechanical properties of metals dealt mainly with single crystals, and showed that a thin surface coating of oxide, and possibly of other salts, increased both the critical shear stress and the stress required to produce further strain after considerable glide had taken place. Oxide films on single crystals of cadmium increased the critical shear stress

by from 50 per cent with the thinnest films up to 150 per cent with the thickest. Contact with an electrolyte containing cadmium ions produced an immediate increase in rate of flow in a loaded single-crystal cadmium wire ; the NO_3 ion had a strongly inhibiting effect, stopping the flow until a 30 to 70 per cent increase in load had been applied. A surface effect has been detected also in polycrystalline lead, but it was only appreciable when the grain size was comparable with the diameter of the specimen. The effect was observed in zinc and in tin and was particularly large in silver, though the film in this case was not visible and must have been very thin. These experiments, like those of Bowden and Tabor, point to the ease with which surface films, having an important influence, can be formed on surfaces ordinarily considered clean.

A paper by Professor Gurney, on the effect of surface condition on the strength of brittle materials, dealt almost entirely with glass, the strength of which he found to be not nearly so dependent on surface perfection as might be expected. At room temperature, plastics were less sensitive to surface defects than glass, but strength was affected by the nature of the surrounding atmosphere.

In a valuable contribution, Mr. R. J. Love presented a fully documented review and critical survey of the influence of surface condition on the fatigue strength of steel. Improved fatigue strength has been obtained by carburising, nitriding, cyaniding, flame-hardening and cold working by rolling, pressing or "pre-setting." Carburising and nitriding, especially, have given marked improvement in fatigue limit. Shot-peening gave variable results depending on the surface to which it was applied and the type of stress to be withstood. Weakness resulted from surface roughness, decarburisation, cold straightening, electro-deposited and hot-dipped metal coatings, metal spraying and acid pickling. This effect of non-ferrous coatings does not refer to corrosion-fatigue conditions. The adverse effect of metal spraying in ordinary fatigue tests is due to the preparation which the surface must receive. Shot-blasting gave the least deleterious results but also gave the poorest adhesion. There were circumstances in which electrodeposited specimens, especially after shot-peening of the plating, were stronger than the unplated ones. Several of the processes which improved fatigue strength set up residual compressive stresses in the surface, and a few weakening processes set up residual tensile stresses ; but, in the author's opinion, there appeared to be insufficient experimental evidence to indicate the degree of influence of these stresses.

Discussion

The discussion covered a wide range of subjects, including the character of the Beilby layer, the interaction of lubricant and metal surface in relation to the functioning of bearings, and the influence of processes affecting the condition of the surface of the metal on the fatigue properties of steel. It will be fully reported in due course in an Institute of Metals publication.

Caustic Cracking in Steam Boilers

Under the auspices of the Corrosion Group of the Society of Chemical Industry, of which Dr. W. H. J. Vernon is chairman, a conference on the caustic cracking of steam boilers was held on November 20th, in the lecture hall of the Institution of Mechanical Engineers. Contributions were received from France, Holland and the U.S.A., as well as from this country. The six papers before the conference, together with the additional contributions made in the course of the discussion, will be of the greatest assistance in any attempt to assess the incidence of caustic cracking under modern conditions and the efficacy of available methods of prevention.

There is no doubt that many boiler explosions reported at an early date were due to service conditions leading to caustic embrittlement, but the cause of failure was at the time largely a matter of speculation. Not until 1917 did the theory of caustic cracking receive any general acceptance. The theory attributed cracking in boilers to the action of concentrated alkali solutions (produced from water-treatment additions by evaporation in the crevices associated with riveting) on mild steel in a state of stress produced in and around the rivets in the riveting process. The cracks were generally associated with rivets or rivet holes.

The first paper, by Dr. C. D. Weir and Mr. P. Hamer, presented a critical survey of information relating to the prevention of caustic cracking by chemical means based on laboratory experiments, field tests and operational experience, including some previously unpublished information. In 1928, Parr and Straub at the University of Illinois concluded that caustic cracking might be prevented by the maintenance of a certain proportion of sodium sulphate in the boiler water in relation to its caustic alkalinity. Various ratios have been recommended by different authorities. For example, the British Standards Institution in its recommended treatment of water for marine boilers suggests that a ratio of sodium sulphate to caustic alkalinity (expressed as calcium carbonate) of 2·0 should be maintained. This corresponds to a Na_2SO_4/NaOH ratio of 2·5. The efficacy of the sodium sulphate treatment was discussed in considerable detail by the authors who concluded that whilst adherence to the ratio might be effective in many cases, there was considerable doubt as to its general efficacy. For example, it was definitely not successful in locomotive boilers, probably on account of the severe and varying stresses they experience owing to the motion of the engine. In this case, organic inhibitors had given more satisfactory results, but treatment by these methods was often difficult to control. American laboratory and full-scale experience indicated that sodium nitrate exhibited a pronounced inhibiting effect. Sodium nitrate or lignin treatment was officially recommended for use in locomotive boilers by the American Railway Engineering Association to the specific exclusion of sulphate, which, it was stated, "was found worthless in railroad service." In the U.S.A. it was recommended that the ratio of sodium nitrate to total alkalinity, expressed as NaOH, should be equal to or greater than 0·4. The co-ordinated phosphate treatment was considered by the authors to be logically the most satisfactory. In this treatment acid phosphates are used to destroy free caustic soda and form trisodium phosphate. Good results were reported from America, and also by the water treatment service of I.C.I.; and similar experience was reported in the next paper by Dr. R. Rath.

Dr. Rath described the history, covering about twenty-five years, of a number of boilers at the Gennevilliers power station, to the feed water of which trisodium phosphate had been added. There was a progressive decrease in the frequency of the cracking observed, corresponding (as shown by analysis) with the presence of more trisodium phosphate and less NaOH in the boiler water. Experience showed that trisodium phosphate exerted a definite protective action against caustic cracking, and that it was desirable to maintain the ratio Na_3PO_4/NaOH greater than unity.

In a communication from the U.S.A., Dr. A. A. Berk claimed that caustic cracking was no longer a menace in boilers in the United States, partly because of the adoption of welded drums and other improved methods of construction, and partly as a result of the research supported by the users through the Joint Research Committee on Boiler Feed-Water Studies at the U.S. Bureau of Mines. Several cases of intercrystalline cracking (mostly in rolled tube ends) were, however, reported every year in boilers which had not been treated. An instrument which had played an important part in the Bureau of Mines' investigations was the Schroeder "embrittlement detector." This consisted essentially of an arrangement to produce an artificial leakage of boiler water in such a fashion that the region of maximum concentration of boiler water coincides with the area of maximum stress in the test specimen. The detector shows whether the actual water in an operating boiler is chemically capable of causing cracking. Dr. Berk referred to the increasing record of parallelism between the results of testing with the Schroeder detector and experience with operating boilers ; and Dr. Weir and Mr. Hamer quoted American statements to the effect that in no case had cracking occurred where a properly conducted detector test had indicated that the water was not dangerous. Dr. Berk described how, by its aid, several effective water-conditioning treatments had been studied. There was now a large background of data to show that nitrate, quebracho tannin, and zero-caustic (co-ordinated phosphate) treatments had been applied successfully to prevent cracking of detector specimens.

Dr. R. N. Parkins, in a paper on the intercrystalline corrosion of mild steels, considered the subject broadly. He made a comparison between caustic cracking and cracking in nitrate solutions, and concluded that caustic cracking was accounted for most satisfactorily by a theory similar to that which he had recently proposed to account for nitrate cracking of mild steel.* Suggestions were put forward in his paper for further work with a view to establishing an explanation of the mechanism of caustic cracking, and a brief review of methods of preventing cracking in riveted boilers, including the possible use of peening, was added.

In laboratory tests, a rapid method of determining the susceptibility of steels to intercrystalline attack is of great value, and Dr. J. Lodder described a new method, developed in the Netherlands, applicable to the investigation of caustic cracking or of intercrystalline attack by nitrates. When the three factors, stress, temperature and concentration, to which the steel is subjected, are raised to an applicable maximum in a pressure vessel, the time of rupture of susceptible mild steel may be cut down to a few minutes, whereas a non-susceptible material remains uncracked after several days.

The conference met again in the afternoon to consider "A Boiler User's View of the Problem of Caustic Cracking in Water Tube Boilers with Riveted Drums," introduced by Mr. R. Ll. Rees of the British Electricity Authority. As a result of the study of the histories of more than 1200 riveted drum boilers, he concluded that the use of sulphate might be continued in the hope of blocking leakage paths in the seams, nitrate being used simultaneously as an inhibitor. More knowledge was needed about the reduction of nitrate in certain boilers and about the possible effect of this upon the degree of protection against cracking. More knowledge was also required about the circumstances in which phosphate and quebracho were effective.

Discussion

The discussion was opened by Sir Harold Hartley who emphasised the need for the investigation of the cause of cracking and the desirability of accumulating detailed records of practical experience. He expressed the hope that the meeting would be able to afford some guidance in the conflict of opinion that had been revealed, and give some answer to the query "Where do we go to, from here ?" Mr. T. H. Turner recalled earlier meetings which had discussed caustic cracking, and in particular a meeting of the Institution of Mechanical Engineers in November, 1942, at which he had advocated some of the preventive measures which had now again been put forward. He emphasised the value to the B.S.I. Committee concerned with boiler-water treatment of full information about material, environment and behaviour, and he asked metallurgists who encountered instances of caustic cracking not to omit grain size measurements and susceptibility to strain-age-embrittlement from their report on the steel. On the materials side, Dr. U. R. Evans, Dr. T. P. Hoar and others discussed analogies and differences exhibited by different forms of intercrystalline cracking. It was clear that analogies should not be pressed too far, and, in particular, the analogy between nitrate cracking and caustic cracking was not so close as to justify susceptibility to nitrate cracking, as measured in Dr. Lodder's apparatus, to be used as a guide to susceptibility to caustic cracking.

The main discussion centred on preventive treatments and, incidentally, on the value of the Schroeder detector. Dr. Berk demonstrated one of these appliances, and the general opinion appeared to be that its value, above that of other tests, was well established both in the laboratory and in the plant. There were clearly strong differences of opinion however, as to the most preventive addition.

*Journal of the Iron and Steel Institute, October, 1952, page 149.

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WOOLWICH ARSENAL

In two world wars the existence of Woolwich Arsenal has been of immense value to this country. In both wars the Arsenal made a large contribution to the total production of armaments. At times, notably during the years of disarmament after the first world war, the whole organisation of the Royal Ordnance Factories has been concentrated there and nearly the whole output of armaments made within the Royal Ordnance Factories organisation has been manufactured there. Those who work at the Arsenal have become highly skilled and for long that factory has provided a fine training ground for engineers. There were trained there nearly all the key personnel necessary to start other Royal Ordnance Factories set up before and during the last war in various parts of this country. Former Woolwich apprentices have always held a high reputation in outside industry and many of them have attained in later life distinction in many branches of engineering. The educational facilities at Woolwich, close to the London technical institutes and including the local Polytechnic, whose reputation has for long stood high, can scarcely be rivalled elsewhere and are certainly not equalled in the neighbourhoods of most other newer ordnance factories. Yet in its twelfth report, published last week, the Select Committee on Estimates recommends that "the question of the use of the Royal Arsenal, Woolwich . . . should be given immediate consideration" and that "the possibility of concentrating the work and releasing as much as possible of the site for other development should be carefully examined."

In truth Woolwich Arsenal has recently fallen upon evil days. It covers an area of 2161 acres and has a river frontage of 3 miles. But, unfortunately, with every development of aerial warfare it has become more vulnerable to attack. In consequence, nobody, least of all the Ministry of Supply and the Armed Forces, cares to see concentrated at Woolwich the production of any particular kind of armament, nor to see placed there even any large fraction of the total output of the ordnance factories. The factory is engaged in filling, ammunition-making, gun-making and vehicle and tank repairing, all of them activities that are being also carried on at least as efficiently and probably at less cost in more modern ordnance factories elsewhere. It gets also experimental and short-run orders. But these orders, as the Committee notes, tend to conflict with any idea that normal productive work should be done in addition. The present number of employees at Woolwich is about 9000. At least ten times as many have been employed there during wartime, so that, even allowing for the essential spaciousness of explosives and filling factories, the total area of the factory is not effectively used. Real costs of production there are unknown for no rent or interest on the capital value of the land occupied is included in manufacturing accounts. Furthermore, nobody cares to expend public money on the modernisation of a factory that is held to be so vulnerable to air attack in time of war. The Committee found not only, as might well be expected, that the factory buildings are old and obsolete, but also that some 50 per cent of existing machinery needs replacement or major overhaul, that no less than 23 per cent is fit only for scrap and that it is difficult to get approval for any new plant for Woolwich unless it is easily movable. Clearly the official attitude to Woolwich Arsenal is hesitant. The Committee wishes discussion of its future to be brought to a head.

As an engineering journal we cannot be expected to have the full and no doubt partly secret information upon which the Services and Ministry of Supply assess the extent of the vulnerability of Woolwich Arsenal to destructive attack in any future war. Yet one thing is obvious enough from the Report of the Committee. The mere fear that the site would prove vulnerable in war is itself acting as a factor limiting the present usefulness of the Arsenal and preventing such active maintenance of its plant and buildings as would preserve its productive capacity for large-scale output in a future war. The plant, in fact, is neither being effectively used nor properly maintained. No doubt it is the memory that in two world wars, in the latter of which it was open to aerial attack, the Arsenal has proved very valuable, that makes those responsible hesitate wholly to close the factory down. Yet it is clear enough from the Report that if the site is as vulnerable as it is held to be the production of armaments would be better done elsewhere, and that, even if the site can be adequately protected, major reconstruction of the buildings and major re-equipment will be necessary. But, since the building of modern factories of equivalent potential capacity elsewhere might cost very little more than the reconstruction of Woolwich, and the release of the present Woolwich site, or much of it, would undoubtedly bring in a large return, the conclusion seems inescapable, though sad, that, whether or not the factory is as vulnerable to air attack as it is held to be, it should in large part be closed down. The Committee suggests, tentatively, that part of the site might be retained for the manufacture and overhaul of plant and machine tools for all the Royal Ordnance Factories. The alternative can be offered that a small part of the site, if properly equipped with modern plant, might be used as a training ground and development establishment for pilot plants and prototypes. Thereby use could be made of the excellent educational facilities and a link maintained with the past high reputation of the Arsenal for training good engineers. But even to those proposals the objection holds that it would be unsafe to concentrate too much of such work at Woolwich. Upon another page of this issue we summarise the recommendations of the Committee. They relate to all the Royal Ordnance Factories as well as Woolwich and contain a number of interesting proposals. In particular there is a reference to the need to reduce the numbers of inspectors in ordnance factories, numbers that, the Report reveals, are very surprisingly large in filling factories, seeing that methods of detecting foreign bodies in ammunition that are truly economical of inspection have been devised and were, we believe, tried out some years ago. Governments regularly pay close attention to the Reports of the Select Committee and we hope that as close attention will be given to this one.

ENGINEERING FIRMS AND THE IRON AND STEEL BILL

The authors of a letter to our contemporary *The Times*, published on Thursday of last week, November 20th, have done engineering firms a service. They have drawn attention to unsatisfactory provisions of the Iron and Steel Bill, now before the House of Commons, provisions that we hope will be amended. Under that Bill, as it stands at present, the supervision of the iron and steel industry given to the proposed Iron and Steel Board, will extend over a field much wider than the closer control exercised by the existing Iron and Steel Corporation. Engineering firms operating their own foundries and forges

and doing for their own purposes a certain amount of re-rolling do not come under the control of the Corporation. But they are included, under the terms of the third Schedule to the Iron and Steel Bill, within the field of supervision of the Board. The duties laid upon the Board that could have relevance to the work of engineering firms are those requiring it to maintain under review productive capacity, research, the training, health and welfare of persons employed, and joint consultation between "producers" and persons employed by them. Furthermore, it will be within the powers of the Board under the terms of the Bill to demand statistical and accounting information, the collection of which in the form required by the Board would put engineering firms to a large amount of trouble and expense.

There is no need here to argue the case against giving the Board powers to interfere in the running of engineering factories. That case is well and fully set forth in the letter to which we have already referred. Sir Alfred Herbert suggested, in a letter to *The Times* of November 24th, that defenders of the Bill may argue that the powers that appear to be given to the Board to interfere in engineering works are not intended to be exercised. It is, in fact, true that certain of the Bill's provisions, notably those relating to new production facilities, do indicate that the Board is not intended to interfere directly in the work of smaller concerns. But, as Sir Alfred wrote, "How oft the sight of means to do ill deeds makes ill deeds done!" If powers are not intended to be exercised it is unsatisfactory that the Board should be given them under the terms of the Bill. Possibly in the framing of the Bill the Third Schedule, which defines what activities are to comprise the iron and steel industry within the meaning of the Bill, was drawn up to cover the activities of foundries, forges and rolling plant in engineering factories because of the difficulty of finding a form of words that adequately draws a line between firms truly engaged in the production of iron and steel and those processing it solely or mainly for their own ends. That difficulty was undoubtedly enhanced by the desire of ironfounders that their raw material requirements should be safeguarded, that their interests should not be subordinated to those of the steel industry, and that an existing fruitful partnership between ironfounders and iron producers should not be broken. That desire, it is felt by most ironfounders themselves, can best be met by bringing ironfounding activities in certain respects under the supervision of the Board and insuring that ironfounders are represented on the Board. But the ironfounders, like engineering firms, are not happy about the wording of the provisions of the Bill relating to production facilities and feel that the powers of the Board to demand information should, at the least, be drastically modified. They feel, too, that iron castings should be excluded from price control by the Board.

Fortunately, the present Government has proved more amenable to argument than that which preceded it, as is particularly demonstrated by the successive amendments by which its proposals for reorganising transport have been improved. It may not be easy to find a form of words or to frame machinery by which iron and steel activities in engineering works are excluded or very largely excluded from the supervision of the Board, whereas similar activities outside that industry are not, nor to frame clauses that will limit the supervision to be exercised by the Board in subsidiary activities, such as ironfounding, whilst leaving it fully effective elsewhere. But to preserve the peace of mind of engineers it is certainly important that more precise and limited definition of the Board's powers should appear in the Bill. For if the interference permitted the Board under the terms of the present Bill in the activities of engineering works did come to be exercised it might prove a sore hindrance to the efficient management of those concerns. As the writers of the letter to *The Times* put it, the casting, rolling and forging of iron and steel in such works are "departmental means to an end," not ends in themselves, as they are in the iron and steel industry proper. We were therefore glad to hear the Minister of Supply, in moving the second reading of the Bill last Tuesday, promise to consider in Committee "amendments designed to remove genuine doubts or to stop unintended loopholes for bureaucracy."

Obituary

S. R. ROGET

We have learned with deep regret of the death of Mr. Samuel Romilly Roget, which occurred in hospital in London on November 17th, after he had collapsed in his office at the headquarters of the British Standards Institution. For the last ten years or so, Mr. Roget had served on the staff of the British Standards Institution, acting during that time as secretary to no less than thirty-one sectional committees. The members of those committees, in particular, will not soon forget Mr. Roget's charming personality and his readiness at all times to help.

Mr. Roget, who was seventy-seven, was the grandson of Dr. P. M. Roget, the author of the *Thesaurus*. For many years, S. R. Roget had undertaken the task of keeping that well-known work up to date. When he joined the staff of the British Standards Institution in 1941, it was to take responsibility for the revision of the *Glossary of Terms Used in Electrical Engineering*. When that task was completed two years later, Mr. Roget agreed to continue at the B.S.I. to take charge of similar work in other fields. Up to the time of his death he was engaged in the preparation of British Standard and other technical vocabularies, among the latter being the *International Electrotechnical Vocabulary*, which is being produced by the International Electrotechnical Commission. There were many other claims upon Mr. Roget's able service. Recently, for example, he had been elected president of the Huguenot Society, of which he had been secretary for a number of years.

DR. G. V. LOMONOSSOFF

As we go to press, we learn with deep regret of the death of Dr. G. V. Lomonossoff, M.I.Mech.E., which occurred at the home of his son, in Montreal, on November 19th. Dr. Lomonossoff, who was well known to engineers in this country and overseas, was in his seventy-seventh year.

INTERNATIONAL AVIATION MEETING.—The Council of the International Civil Aviation Organisation (I.C.A.O.) has accepted the invitation of Her Majesty's Government to hold the seventh session of the Assembly of the Organisation at Brighton beginning June 16, 1953.

Engineering Research Report, 1951

The report of the Mechanical Engineering Research Board, the second since its appointment in 1946, has now been published. It refers to the transfer of the Engineering Division of the National Physical Laboratory, to the present establishment at East Kilbride, and notes that apart from the staff engaged on creep research only a small thermodynamic team remains in the south.

The research programme is conducted under seven distinct divisions and the report contains detailed notes of the work in hand of each division. Divisions A and B are concerned with the properties and strength of materials and the mechanics of solids, stress analysis and vibration, and the report notes that a comprehensive programme of work on fatigue continues upon aluminium alloys. The basic properties of magnesium zirconium alloy sheet are now being determined and mention is made of certain imperfections in its production which have led to premature failures. The report reviews the work previously carried out on the study of creep and mentions that work during the year was devoted to tests on isotropic copper at room temperature and at 250 deg. Cent. The main work in Division C, which is concerned with the mechanics of fluids, was the planning and design of special equipment for its own use. One item of research mentioned in the report is concerned with the pumping of peat over large distances, and the performance of a proprietary pump and the determination of the most economical pipe diameter are being investigated.

In Division D, dealing with lubrication, wear and mechanical engineering aspects of corrosion, the report first refers to some aspects of hydrodynamic lubrication.

The behaviour of a journal bearing running eccentrically in a bush has been studied to check the validity of Sir Geoffrey Taylor's criterion for critical speed, which was worked out for one cylinder rotating concentrically inside another. Results of experiments so far show that the designer who arranged that Taylor's value was not exceeded would be on the safe side. This research is important because of the advent of the gas turbine and the introduction of other rapidly rotating machinery.

Mention is then made of scuffing, which is a form of surface failure involving transfer of metal from one surface to another when in rubbing contact, as in gear teeth. From preliminary tests a tentative theory has been evolved. Except under full fluid-film lubrication there will always be a few points of momentary intimate contact between rubbing surfaces. Here the pressures and coefficients of friction will be high and considerable heat will be generated. At some critical condition of load and speed, depending on the rubbing combination, the heat will not be dissipated in the lubricant and surrounding bulk material. The temperature will rise and this will lead to a change in area of contact, coefficient of friction, or other factor, sufficient to cause thermal instability. The temperature will then go up rapidly until the melting point of the material is reached.

One special problem studied was the behaviour of four materials suggested for the ankle joints of artificial limbs. The joints were tested as if they were being used by a person weighing 12 or 13 stones and were not lubricated. Two types of sintered bronze were found to be more satisfactory than certain plastic materials. Apart from the work on scuffing, two power circulators are being used to test spur and helical gear life. High-speed gear pitting is being studied extra-departmentally by a firm of gear manufacturers and by the University of Durham, and dynamic stresses in gear teeth are being determined at the University of Cambridge.

The remainder of the report is concerned with the other three divisions of the establishment—mechanisms, metrology, and noise control (Division E); mechanics of formation and machine shaping of materials (Division F); heat transfer and applied thermodynamics (Division G).

The report is published for the Department of Scientific and Industrial Research by Her Majesty's Stationery Office, price by post 2s. 1½d.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE DETERMINATION OF THE INLET DIAMETER OF SPIRAL CASINGS OF LARGE FRANCIS TURBINES.

SIR,—In reading your American correspondent's contribution on "Hydraulic Turbine Construction in America," published in your journal of August 29th, pages 297–299, I found particularly interesting the table on "Some Hydraulic Turbines with Welded Spiral Casing," page 298, for it gives the size of the inlet diameter of the spiral casing for ten typical Francis turbines, varying in ratings from 45,000 h.p. to 165,000 h.p., and total heads from 112ft to 480ft.

For some years past I have made a special study of the design factors of water turbines, and derived a series of formulæ, one of which enables one to determine quickly the inlet diameter of spiral casings of Francis turbines.

On examining carefully the data contained in your table, I found that my accurate formula for the inlet diameter gives values which check up remarkably well with those indicated in the table.

As my simplified formula might prove of interest to water turbine designers, I take the opportunity of presenting it below.

$$D=\frac{1\cdot184}{\eta_T^{\frac{1}{2}}\cdot k^{\frac{1}{2}}}\left[\left(\frac{N}{H}\right)^{\frac{1}{2}}\frac{1}{H^{\frac{1}{4}}}\right] \quad . \quad . \quad . \quad (1)$$

where :

D=inlet diameter of spiral casing in feet.
N=rating of turbine in h.p.
H=total head in feet.
η_T=turbine efficiency.
k=head ratio factor=h/H.
h=head, corresponding to the velocity at inlet to spiral casing in ft/sec=$(2gh)^{\frac{1}{2}}=(2gkH)^{\frac{1}{2}}$.
v=velocity in ft/sec.
g=gravitational acceleration in ft/sec².

The above formula (1) is based on a density of water, at 62 deg. Fah., of 62·288 lb/ft³.

Substituting

$$\psi=\frac{1\cdot184}{\eta_T^{\frac{1}{2}}\cdot k^{\frac{1}{2}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

one obtains

$$D=\psi\left[\left(\frac{N}{H}\right)^{\frac{1}{2}}\frac{1}{H^{\frac{1}{4}}}\right] \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and therefore

$$\psi=\frac{D}{\left[\left(\frac{N}{H}\right)^{\frac{1}{2}}\frac{1}{H^{\frac{1}{4}}}\right]} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The values ψ based on the rating in h.p. and the head in feet contained in your table, are indicated in column 6 of my Table I, for the ten typical Francis turbines published on page 298. It will be observed from my Table I that for ratings from 45,000 h.p. to 165,000 h.p., and heads from 112ft to 480ft, the value ψ varies only from 2·771 to 3·035, i.e. about 10 per cent, the average for the ten values being 2·942.

It follows from my expression (2) that the factor ψ depends on the turbine efficiency η_T, and head ratio factor $k=h/H$. In order to demonstrate this, I present in Table II for typical

TABLE II

$$\psi=\frac{1\cdot184}{\eta_T^{\frac{1}{2}}\cdot k^{\frac{1}{2}}}$$

η_T	k	ψ
0·90	0·03	3·000
	0·035	2·886
	0·040	2·791
0·88	0·03	3·034
	0·035	2·918
	0·040	2·823
0·86	0·03	3·068
	0·035	2·952
	0·040	2·855

cases the values ψ for η_T=0·90, 0·88, 0·86, and for k=0·03, 0·035 and 0·040. It is apparent that for this range of assumed values for η_T and k, the factor ψ varies from 3·034 to 2·791, which compare remarkably well with those derived from actual values in Table I, used in practice.

J. R. FINNIECOME

Sutton Coldfield, Warwickshire,

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

SIR,—Professor M'Ewen, in his letter published in your issue of November 14th, and referring to a leading article in your issue of October 24th, stated : "I am not aware that the Institution of British Agricultural Engineers, as such, had any part in the establishment of the M.Sc. in agricultural engineering of this University." As this statement implies that your leader was inaccurate, I have been asked by my Council to inform you of the facts.

Whilst it is true that the Institution, as such, took no actual part in conjunction with Durham University in the establishment of the degree of M.Sc., the Institution was one of several bodies which had been actively campaigning for the setting up of such a degree.

Lt.-Col. Philip Johnson, C.B.E., D.S.O., M.I.Mech.E., Hon.M.I.B.A.E., who at that time was president of the Institution, strongly supported the idea in public on many occasions. It is considered, therefore, that it is quite correct to say that this Institution was associated with the establishment of this degree.

My Council is in complete disagreement with Professor M'Ewen's statement that there is provision for the agricultural engineer who is professionally qualified within the scope of the Institutions of Mechanical and Electrical Engineers.

While agricultural engineering is by no means a new science, and is probably, in fact, one of the oldest forms of engineering, it is becoming increasingly recognised that it is in fact a science which differs in many respects from the other forms of mechanical and electrical engineering. It has to be approached, not only through engineering and physical science, but also through biology and agriculture, and these do not come within the scope of the three major engineering institutions.

The Institution of Mechanical Engineers has, it is true, now set up a paper in agricultural engineering in its examination for associate membership, but it is only one among several optional subjects laid down in the syllabus which may be taken for this examination, and is not in itself a qualifying examination for proficiency in agricultural engineering. In other words, although the corporate members of the three major engineering institutions may be qualified to deal with some specific aspects of agricultural engineering, there is undoubtedly a need for a separate institution to serve those engaged in the industry and to cater for the requirements of the subject in its widest aspect.

It is surprising to learn of Professor M'Ewen's attitude towards the Institution of British Agricultural Engineers as he has been a corporate member for five years and was at one time vice-chairman of the Northern Centre.

R. E. SLADE
Secretary.

The Institution of British Agricultural Engineers, London, W.1,
November 24th.

TABLE I—*Value ψ for Some Hydraulic Turbines*

$$\psi=\frac{D}{\left(\frac{N}{H}\right)^{\frac{1}{2}}\cdot\frac{1}{H^{\frac{1}{4}}}}$$

Item	Power company and station	Rating of turbine (N), h.p.	Total head (H), ft	Inlet diameter of casing (D), ft	in	Factor ψ
1	Aluminium Company of Canada, Shipshaw	100,000	208	16	0	2·771
2	T.V.A. Fontana project	91,500	330	12	0	3·072
3	Carolina Aluminium Company, Che ah unit	45,000	188	12	0	2·872
4	U.S. Bureau of Reclamation, Grand Coulee	165,000	330	15	0	2·859
5	U.S. Bureau of Reclamation, Hoover am	115,000	480	10	0	3·024
6	U.S. Bureau of Reclamation, Hungry Horse dam	105,000	400	11	0	3·035
7	City of Seattle, George project	82,500	280	12	6	2·978
8	U.S. Bureau of Reclamation, Shasta am	103,000	330	12	3	2·956
9	U.S. Army Corps of Engineers, Bull Shoals development ...	62,000	190	14	8	3·014
10	U.S. Army Corps of Engineers, Fort Randall development	57,500	112	19	9½	2·840

Short Notices

Direct Current Machines for Control Systems. By Professor A. Tustin, M.Sc., M.I.E.E. London : E. and F. N. Spon, Ltd., 22, Henrietta Street, W.C.2. Price 50s.—The aim of this book is to describe the various d.c. machines that can be used as "rotary power amplifiers" in automatic control systems. It begins with a useful attempt to establish the principles that are common to various commercial forms of multi-stage generators or rotary amplifiers, which form the basis of automatic control systems. The author emphasises the fact that much of the general theory of automatic control systems is identical with that of feed-back amplifiers in radio. With this approach, the subject is introduced in terms that should be readily intelligible to electrical engineers. Much of the text is devoted to a study of the time constants of d.c. machines and the dynamic characteristics of d.c. generators and some simple combinations of these machines. This treatment leads up to an analysis of cross-field and armature-excited dynamos, including the Rosenberg generator, the "Amplidyne," the "Metadyne," and the "Magnicon." Subsequent chapters deal with machines with heterogeneous pole systems, simple forms of feed-back, cumulative feed-back systems, self-excitation, the three-field generator and unasymmetrical forms of cross-field machines. Finally, torque motors and linear stroke motors are considered. In this admirable introduction to the theory of d.c. machines for control systems, the author has succeeded in showing that an intelligible account of the subject can be given without resorting to higher mathematics, unless very specialised treatment is required.

Ceramics and Glass. London : Her Majesty's Stationery Office, York House, Kingsway, W.C.2. Price 25s.—This is Vol. 10 of the Selected Government Research Reports which are being published for the Department of Scientific and Industrial Research. The volume contains thirteen reports of research work carried out during the war by the Ministries of Supply and Aircraft Production. Ceramics are dealt with in nine reports in the first part of the book, and glass in four reports in the second part of the book. The nine reports on ceramics include studies of their mechanical behaviour at normal and high temperatures, and under varying conditions of temperature and loading, particularly those met with in the operation of gas turbines. The reports dealing with the properties of sintered alumina include one on its use as an insulator for aero-engine sparking plugs. Some experiments on the hot pressing of zirconium carbide powder at 2000 deg. Cent. are also described. The reports on glass research deal with delayed fracture in glass ; the effect of the surrounding atmosphere on the delayed fracture of glass ; fatigue in mineral glass under static and cyclic loading, and the testing of glass optical flats, gelatine filters and register glasses for use in aircraft cameras.

Recent Developments in the Machinability of Steel

INSTITUTION OF MECHANICAL ENGINEERS

At a general meeting of the Institution of Mechanical Engineers on Friday, November 21st, a paper, "Recent Developments in the Machinability of Steel," was presented for discussion by Mr. K. J. B. Wolfe.* We give below a summary of the paper and some of the points made by speakers in the discussion.

Summary

A description of the term "machinability" is given, and it is shown that the behaviour of the metal being machined, called "true machinability," and also the conduct of the tool, known as "cutability," are separate and distinct factors in the metal cutting process. The action of cutting fluids is shown to be a modifying factor.

Recent work at the B.S.A. Group's Machinability Research Laboratories in the field of "true machinability" is described, and includes the effects on this property of hardness, rate of work hardening, microstructure, manganese segregations, and the size of lead globules. The effects on surface finish of speed in turning and some aspects of interest which arise under conditions of intermittent cutting, such as shaping, are included.

Under new work on "cutability" is mentioned the modifying effect on that factor of surface austenite, produced by grinding, and metallic segregations, as shown by micro-radiography. A general description is given of the properties and performance of milling cutters produced by a casting process. Developments in the field of cutting fluids are noted.

Future trends in the development of all the important fields of machinability are especially discussed, in view of the present alloy shortage. The use of ceramic materials and low tungsten and molybdenum high-speed steels as cutting tool materials is mentioned, and also the application of new cutting techniques such as the "hot spot" and electrolytic/electro-erosion methods. Suggestions are made for improvements in both machining stock and cutting fluids.

Discussion

Mr. O. Rendell, who opened the discussion, said that on the "Method of True Machinability Testing," he joined issue with the author, who gave reasons for using drills to determine true machinability. There were four reasons stated :

(1) The machining conditions are under complete control.

(2) Standard drills can be produced without undue difficulty.

(3) The results can be obtained in a reasonable period of time.

(4) Only a small amount of each of the steels under investigation is needed for the test.

He agreed with the author in regard to the last two conditions ; they were very valid reasons for using drills. On the other two reasons, he did not agree at all. As to the machining conditions being under complete control, his own experience of drilling operations led him to say that if the author was able to have complete control of drilling, he was a wizard. On the question of standard drills being produced without difficulty, would the author say what he meant by a standard drill ? If the measurement of standard was the size of the hole a drill would produce, then there was no standard drill. If one took any drill produced commercially over ½in (and this applied to the products of the author's firm as well as to those of any other firm) and drilled a hole using a socket that ran true and a spindle that ran true, one would produce holes varying from 5/1000 to 20/1000 bigger than the size of the drill. Power-adjusted tools were unreliable, particularly after penetration an inch or two deep. The cuttings got jammed between the whole and the drill, and one got an increased load which was not caused by removing the metal. Surely in testing for machinability one should get rid of as many variables as possible. So why have two cutting edges if they both cut at once ? If the tests were carried out on a simple turning operation, then one had only one cutting edge which could be easily controlled, and the actual cutting could be observed—which, of course, was impossible down at the bottom of a drill hole.

The section of the paper, "Engineering Factors Influencing True Machinability," contained some very interesting statements, and Mr. Rendell said that he was well aware of the advantages of high-speed cutting with fine feeds on certain operations, but he felt that the system of machining was often used when better results could be obtained by slow speeds and coarse feeds. In his own factory they had never yet succeeded in producing a fine-finished hole in mild steel when they bored with high speeds and fine feeds. That was not a reliable basis. In these days, when it was possible to lap cutting edges to a very high degree of finish, the slow cutting speeds down to as low as 10ft to 15ft per minute with holes in steel of 1½in and a feed of 1/16 to 1/8, enabled very fine results to be obtained.

The subject of cutting compounds was mentioned in the paper. There was not the slightest doubt that it was not realised as much as it should be what an influence the cutting compounds could have on a machine.

Mr. K. J. B. Wolfe, in his reply to the points raised by Mr. Rendell, said that on standard drilling the machining conditions were under complete control. To be perfectly honest, they had not been quite sure about this, and that was the reason they had devised the experiment for statistical analysis. He felt that they had been completely justified by the results that had been obtained.

What was meant by the phrase "standard drills can be produced without undue difficulty" was that the drills could be produced from the same bar, machined together, heat-treated together, and then tested together, and it would be found that under test conditions those drills that had been made together would all show very nearly the same number of holes to failure. He was not saying anything about the size of the holes they were getting from that, because he agreed with Mr. Rendell on that point.

Mr. P. Grodzinski said that recently Dr. Spaeth had introduced a somewhat new approach to the cutting time diagram. It was quite a big simplification. Instead of using the cutting time—tool life, as it was called—expressed in minutes, one used the length of the path the cutting edge had made before it was worn.

There were in the paper the expressions "machinability" and "cutability." He had read this word "cutability" for the first time in this paper, and he was not altogether happy about the definition. Being interested in simplification, he wondered whether too much use was not made of these "abilities."

Mr. J. C. Z. Martin noted that the author mentioned in the introduction to the paper that the general conception of machinability should be subdivided into "true machinability," i.e. the behaviour of the material being machined, and "cutability," this latter term to cover the conduct of the tool. He strongly supported this contention and believed that unless it was widely accepted future research into practical machinability would make little real progress.

The numerous variables involved in any metal-cutting process, including the cutting tool, the machine tool, the cutting fluid and machining conditions, all played their part, and unless they were standardised no universally acceptable definition or unit of "true machinability" was possible.

The inherent or true machinability of a material could then be established as the cutting force or cutting temperature obtained under standardised conditions. This would broadly correspond to the definition quoted by the author, namely, "that complex property of a material which controls the facility with which it can be cut to the size and shape required commercially." In his definition the author also included surface finish. But this property, although to a certain extent inherent in the material, should, he believed, be treated separately. Tool life, one of the most important factors in machining, would be included in what the author described as "cutability," defined as the conduct of the tool during the cutting process.

Experience and test results indicated that those two properties, "true machinability"—i.e. force or temperature—and "cutability"—i.e. tool life—generally coincided. In other words, the merit ratings of a number of steels based on those two properties were generally similar. There were, however, exceptions.

He would be glad to have the author's views on whether manganese segregation might not be one of the main causes of the apparent lack of correlation between cutting force and tool life occasionally found in machining tests on steels.

Mr. J. H. M. Higginbotham said that the cutting process, or the mechanism of cutting, even in the most simple form that one could devise, was extremely complicated and there were many variables present which were interconnected so that it was indeed difficult to isolate the effect of any one of them. He thought it was asking rather a lot to try to use a test such as drilling, whereby there were more complications involved ; there were velocity gradients from the centre of the tool to the outside, there was a tendency to swarf jamming and one was also operating on quite a small section of the workpiece ; he thought that in any test of this nature it was as well to cover as much of the workpiece as possible within reasonable limits in order to get a true statistical average naturally. The results obtained, however, must have some value, but they were of a specific nature when referring to drilling operations.

Mr. Morton, referring to the use of drilling tests for machinability rating, said that he had been associated with drill testing and the use of drilling tests for rating machinability and cutting fluids for some ten or twelve years, and he could assure Mr. Rendell that the undoubted difficulties which he had indicated could be overcome. They called for a great deal of effort, as he knew from experience, but one could bring the variants down to figures such as the author had quoted. He added further that his experience on turning tests had shown that there the amount of variance one got was not so very much less than on drilling, so that on that ground alone it would not really be advisable to change over to turning.

He asked the author, in connection with drilling, whether he was quite satisfied that

* Deputy Director of Research to the B.S.A. Group of Companies.

drilling tests gave a reasonable indication of the general machining properties of a material, and whether they could be safely taken to indicate the material's behaviour in turning, milling, and so on.

In the paper there was a section dealing with "Engineering Factors Influencing True Machinability." The effect of intermittent cutting was very interesting, and certainly was the first piece of work which he had seen on that subject; it was very long overdue. The author did not mention in that section the influence of diameter of workpiece. He believed it was the general experience that as one went from smaller diameters, machining became more difficult; in fact, he had been shown a normograph for cutting speeds which claimed to take that factor into account.

In dealing with the effect of speed on turning, the author said very truly that, provided other things were equal, there was no doubt that speed determined the efficiency of the continuous cutting operation more than any other single factor. It was perhaps a pity, if only for the sake of completeness, that the author had only shown the influence of speed on surface finish.

The mention of these factors led him to the next point; it was that the rating of machinability was a very difficult and complex subject. In the workshop, however, people were mainly concerned with three factors—tool life in relation to speed, surface finish and, to a lesser extent, cutting forces. The last factor perhaps was of more interest to the machine tool manufacturer. He had wondered for a long time whether it would not be possible, at least within groups into which materials would naturally fall, to prepare tables of tool life, surface finish and cutting force obtained under appropriate standardised conditions.

Dr. Hugh Ford said that the fundamental investigation of machine shaping processes clearly presented many difficulties, but it seemed to him that the progress which had been made lately in basic ideas on metal deformation could to some extent be applied, and this might have some effect on the rather numerous qualitative terms which one found throughout the present paper and many other papers.

It was necessary, if one could not measure some fundamental property of a material and relate that to the properties of a given process, to describe in some qualitative terms the experiences one had with that metal-working process. It seemed to him that this was the reason for such terms as "true machinability," "machinability index," "cutability," "finishability," and possibly, as had been suggested earlier, "formability." The index which had been used in the paper seemed to be a little lacking in definition, and he was not at all clear what was meant by "true machinability index." But it seemed to be related to the drilling of holes particularly, and he was wondering whether, in fact, they ought not to call that "drillability" and have similar terms as "turnability," "shapability," "planability" and even "nibblability."

When it came to suggesting a term "work hardenability" he was afraid that he really began to take issue with the author, because there were some quite clear notions on the rate of work hardening of materials and one did not need to have some qualitative term such as "work hardenability" to describe them. Indeed, he thought that the metallurgists had already made use of the word "hardenability"—much as he disliked it—as a measuring of the depth to which a steel would harden on quenching.

His point in these remarks was to make a plea for a rather more fundamental investigation of some of these characteristics of cutting processes to see whether they could not get something which they could measure, because until they did that it was undoubtedly true that they would have the sort of discussion which went around many different kinds of test, many different indices and all the frightful terms to which they had been introduced.

Mr. K. J. B. Wolfe, in a brief reply to some of the points raised in the discussion, said that he entirely agreed that a more fundamental outlook should be taken towards this class of work. However, it must be borne in mind that one knew what went on very often in the case of chemical reactions, and one knew what went on when a metal was work hardened in certain specific cases; but one just had not the mathematical analytical ability at the moment really to put down in black and white just what went on in those specific cases. The mathematics would be far too complicated, he thought, to take into account everything that went on and would go on.

Mr. Morton had dealt with the drilling test versus milling and had raised the question whether from certain drilling tests it was possible to say how a metal would behave in cases of turning, milling, and so on. It was possible to do that very definitely within practical limits. Enough work had been done with drills to be able to translate the results obtained from drilling into shop use. From drilling tests it was possible to say how the material would probably behave during turning, milling, tapping and so on.

There had been a question from another contributor about why drills were used instead of turning tests. It was very difficult indeed to get a lathe of small size on which one could get really uniform material and get really reliable results on the turning test.

Mr. Martin had asked whether in the manganese segregation one of the causes for the results during machining might be found. That certainly was one of the causes certain force measurements fell down with regard to tool life, but he would also say that if one had a lot of non-metallic inclusions, such as alumina, that could also lead one "up the garden path" as far as tool life and tool forces were concerned.

Royal Ordnance Factories*

THE question of the use of the Royal Arsenal, Woolwich, and its fuller integration with the whole organisation of the Royal Ordnance Factories should be given immediate consideration by the Royal Ordnance Factory Board, the possibilities of concentrating the work and releasing as much as possible of the site for other development should be carefully examined, and a decision should be reached at the earliest possible moment;

An early effort should be made to devise an incentive system for all non-productive industrial workers;

Further consideration should be given, in consultation with the trade unions concerned, to the recruitment and training of rate fixers and to the methods of fixing piece rates in the guns, carriages and tanks factories;

The Director of Ordnance Factories (Accounts) should be made a member of the Executive Board of the Royal Ordnance Factories as soon as possible;

The liaison between planner and producer in all the groups of Royal Ordnance Factories, except the explosives group, should be standardised as far as possible, and the liaison should be started as early as possible in the process of developing a project;

A list should be made of all components for lack of which production would be completely disorganised, and in no circumstances should contracts for such components be awarded only to one firm, or at any rate they should not be concentrated in one factory;

A way should be found of associating the Royal Ordnance Factories organisation much more closely with the production departments of the Directors-General of Armament Production and of Fighting Vehicles, both in the placing and in the progressing of orders;

The Superintendents of Royal Ordnance Factories should have powers to purchase stocks of materials within a limit substantially higher than £1000;

A section should be set up under the Director-General with complete responsibility for the purchase of machine tools, subject only to the present approval, on grounds of scarcity, of the Controller of Machine Tools;

Should the last recommendation prove unacceptable to the Ministry of Supply, demands for new plant, if they are agreed by the headquarters of the Royal Ordnance Factories and by the Controller of Machine Tools, should be treated as accepted, and passed forthwith to the Contracts Branch of the Ministry;

Whether or not the Royal Ordnance Factories are given the responsibility of purchasing their own plant, the limit of £250 on capital expenditure by Superintendents should be increased, provided that the need for standard equipment is not neglected;

A sum should be made available to each Superintendent to spend on process research, and Superintendents should not be required to give in advance more than a general statement of the lines along which the research is to be conducted;

The Royal Ordnance Factories should have power to fix their own establishments of junior non-industrial staff, subject only to supervision from their own headquarters;

The Ministry of Supply should, in consultation with the Treasury, devise some means of exempting the junior posts of the non-industrial grade from any order limiting recruitment of Civil Servants;

The Treasury should make every effort to introduce experimental sick-pay changes in a few of the Factories, as suggested by the staff of the Medical Research Council, who investigated the working of the sick-pay scheme;

The training school of the Royal Ordnance Factories should continue to be developed;

Courses in industrial problems and joint consultation should be run there for shop stewards;

Courses in subjects relating to cost control should be run there for supervisory and technical staff;

The fourteenth recommendation summarised here should apply equally to the non-industrial staff of the inspectorates of the Chief Inspector of Armaments and the Chief Inspector of Naval Ordnance;

A committee should be set up immediately with instructions to report at the earliest possible date on the steps to be taken to reduce the numbers and duplication of inspectors and so to avoid the unnecessary disturbance of the Factories' production programmes.

* Twelfth Report of the Select Committee on Estimates, relating to the Royal Ordnance Factories. Summary of Recommendations.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

MILLING CUTTERS AND REAMERS

No. 122 : 1952. This is Part II of the revised B.S. 122, and has broadly the same scope as the corresponding section on reamers, countersinks and counterbores, in the previous edition. The principle of indicating preferred sizes has been adopted, and the limits of tolerance on the cutting diameters have been revised. A section giving the nomenclature of the various component parts and features of reamers is also included, and more specific requirements and recommendations are given throughout the tables on matters of detail such as back taper and bevel lead. Work on the revision of the milling cutter section of the standard has now been completed, and it is hoped that Part I: Milling Cutters, will be issued shortly. Price 15s.

A Thermal Relay for Protecting Induction Motors

THE accompanying illustrations show the general arrangement of a new form of thermal relay which has been developed for the protection, against prolonged overloads, of induction motors on continuous duty. This device is a product of Chamberlain and Hookham, Ltd., New Bartholomew Street, Birmingham, 5.

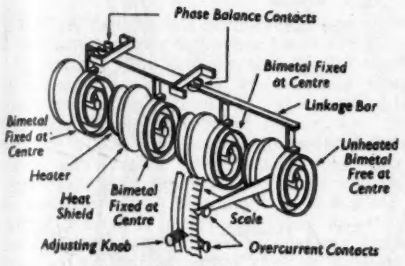


Fig. 1—Bimetal Assembly

Three models of these relays are now available. One, the "H" relay, is designed to protect three-phase star- or delta-connected induction motors against overload or single-phasing conditions where the starting current does not exceed seven times normal full load. Similar protection is given by the "HST" relay for larger motors having starting currents in excess of seven times full load and where starting conditions may be prolonged by high inertia loads. Instantaneous protection against short circuit faults is an additional protection obtainable in the "HST/AM" relay; in all other respects this relay (Fig. 5) is similar to the "HST" relay.

The principle of operation of the "H" relay is that three bimetal spirals (Fig. 1), fixed at their centres, receive heat from three metal grids carrying currents proportional to the three line currents energising the motor. The deflection of each bimetal spiral is directly related to the current in its associated heater—and, of course, to the ambient temperature—but the relative movement of the free ends of the spirals is only a function of the difference between the currents flowing in the associated motor lines.

The free end of the central spiral, Fig. 1, is terminated in two forked contacts, the members of which "embrace" single contacts secured to the other two spirals. Each fork has its prongs spaced so that a 12 per cent difference in the currents of adjacent elements will cause engagement of the appropriate single contact. These relay contacts will then actuate a breaker operating system as well as the indicator described later. Thus, any phase unbalance of 12 per cent at 100 per cent load will operate the protective device.

There is a fourth bimetal spiral; it has no associated heater and is sensitive only to changes of ambient temperature. The outer end of this bimetal spiral is attached to the free end of one of the heated spirals described above and the inner end, which is freely pivoted, is attached to an arm terminating in a contact. Movement of this contact depends only on the heat supplied to the adjacent heater bimetal spiral, since the deflection of the unheated spiral due to ambient temperature change is in the opposite direction to that of the heated bimetal. A scale is fixed in proximity to the contact arm, calibrated in percentage of full load, and an adjustable contact is arranged on the scale so that it may be engaged by the contact arm at any pre-determined line current between 50 per cent and 150 per cent of normal full load. This device provides overload protection.

The spirals, which are heat-aged during manufacture and gold-plated to ensure no change in surface texture, are individually calibrated and groups of four spirals having the same constants are selected for each unit. Tripping indicators, of conventional attracted armature pattern operated electrically when the main contacts close, can be fitted to any model.

The indicator can be arranged to be connected in series or parallel with the trip coil. Each contactor is fitted with two changeover contacts, which can be connected as two nor-

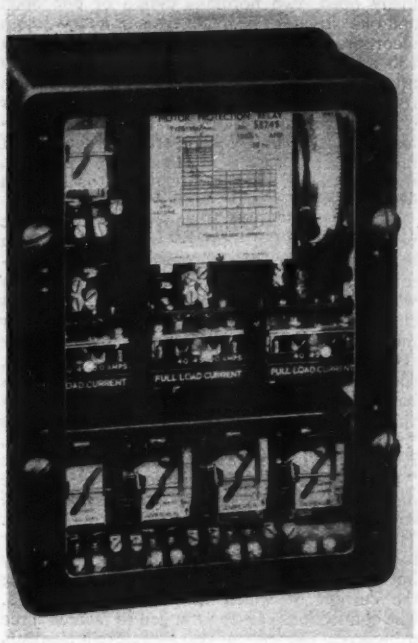


Fig. 5—"HST/AM" Relay with All Indicators Showing Faults

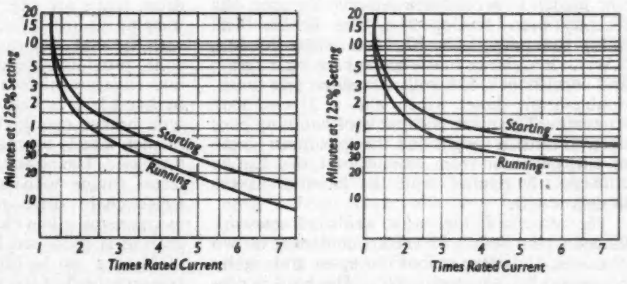


Fig. 3—Characteristics of "H" Relay (left) and "HST" and "HST/AM" Relays (right)

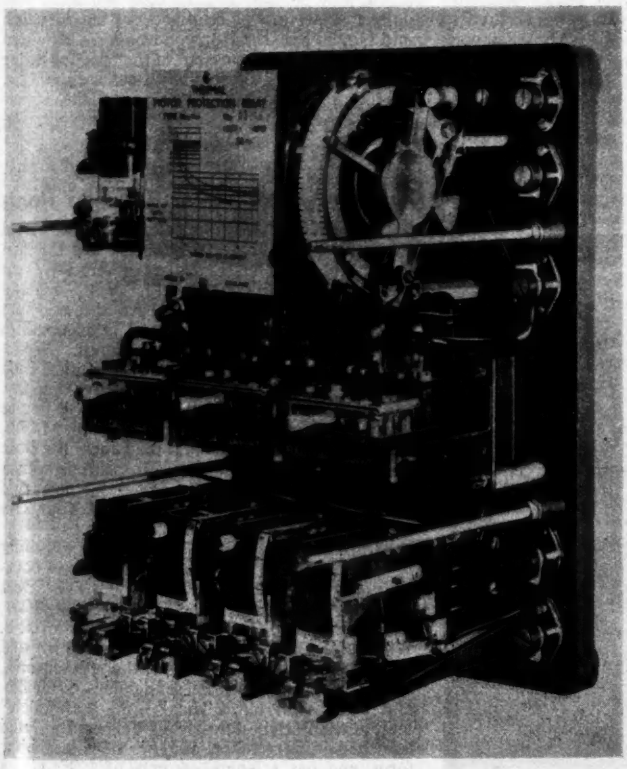


Fig. 2—"HST/AM" Relay with Cover Removed

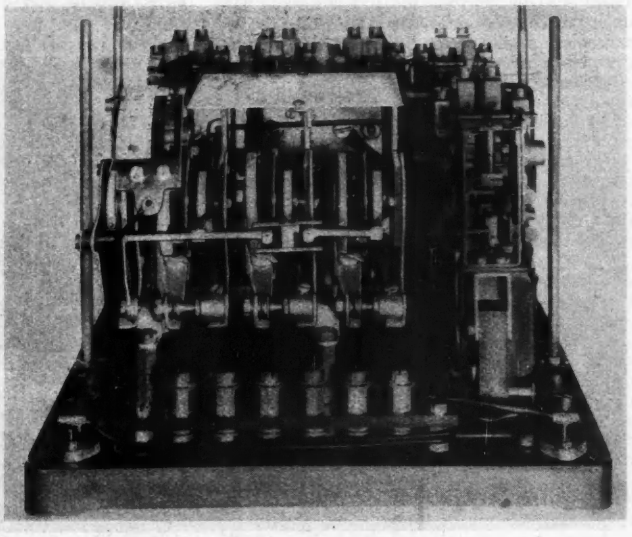


Fig. 4—Bimetal Spirals and Relay Contacts

mally open, two normally closed or one open and one closed. The indicator is of a new design incorporating a flap, which is rotated through 180 deg. about one horizontal edge. The flap normally covers a plate of its own size but on rotation exposes the plate, together with its own reverse side. In Fig. 5 the thermal overload indicator in the top left hand corner of the instrument case is in the operated position, showing a fault. In Fig. 2 the indicator is shown in its closed position.

The "HST" relay is designed on the same principles but the heaters are supplied from three saturable transformers. These transformers are designed to be saturated in such a way as to modify the operating time current curve and thus allow a larger starting time for motors with high inertia loads. Also, heavy starting currents can be accepted by the relay, since the output current of the transformer is considerably lower in proportion to the input current than in the "H" relay. The "HST/AM" relay, which is illustrated in Figs. 2, 4 and 5, incorporates all the features of the "HST" relay and in addition is fitted with three instantaneous relays, type "AM," each connected in series with a saturable transformer. The instantaneous element is essentially similar to the tripping indicator described previously but includes a setting adjustment for selecting the current at which it should be operated. The connections can be arranged to include three overcurrent elements or two overcurrent elements and one earth fault element.

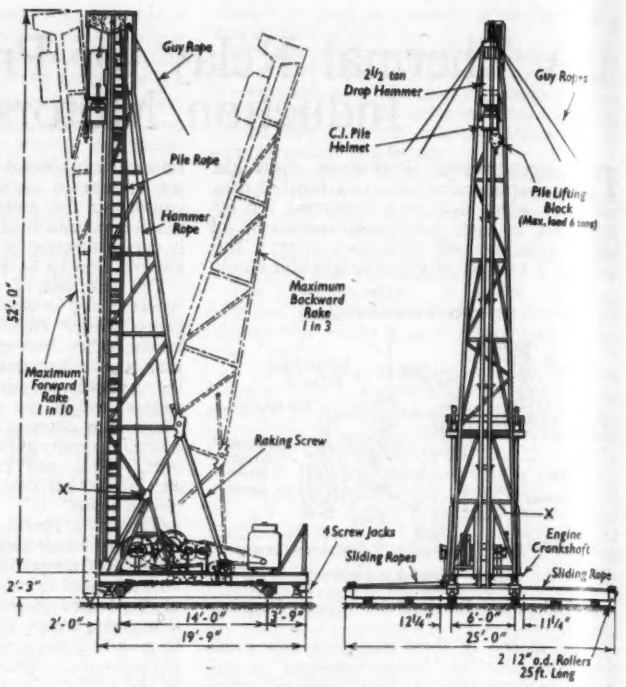
The version illustrated in Fig. 5 shows four indicators, each in the operated position, mounted in a horizontal row near the bottom of the casing. From left to right the four indicators show, respectively, phase unbalance, instantaneous over-current, instantaneous earth fault and, again, instantaneous over-current.

A 52ft Portable Pile Driving Plant

A PILE driving plant designed for transport by low loader as a complete self-erecting unit, has recently been developed by the British Steel Piling Company, Ltd., 10, Haymarket, London, S.W.1. It is shown in the accompanying diagram and consists of a 52ft roller mounted pile frame, double-drum diesel winch and a 2½-ton drop hammer. The plant is capable of handling piles up to 6 tons in weight and the maximum length of pile, measured from ground level, that can be conveniently pitched with the hammer in the leaders is 45ft.

The superstructure is a welded framework hinged to the base, with leaders consisting of two channels, 8in deep, spaced 6in apart and rigidly connected by cast steel yokes. The head is provided with two main sheaves and one guide sheave for the hammer and pile lifting ropes; there are attachments for the four guy ropes and return end of the pile rope. A ladder is fixed to the side of the frame to give access to the head and intermediate stages.

Raking gear is fitted, which may be either hand operated or power driven from the winch. The maximum permissible working inclinations are 1 in 3 backward and 1 in 10 forward. The raking gear is also used for folding the plant down for transport. For this purpose the main front support pins are removed and the superstructure is made to pivot on pins, marked *X* in the diagram, passing through two A-frame bearings on either side of the base. Lowering may then proceed using the raking screws, the time required from vertical to horizontal with power operation being approximately nine minutes. Our second illustration shows the frame lowered for transport.



Arrangement of 52ft Portable Pile Driving Plant

The base is also mainly of welded construction and is fitted with bearings for mounting on two 25ft by 12in O.D. rollers. Brackets carrying sheaves are attached to the main longitudinal members, to guide the rolling and sliding ropes from the warping drums of the winch. Four screw jacks are built on to the underside of the base for use when pulling the rollers through, for moving the plant sideways, and for loading for transport.

The winch has two drums mounted on shafts between welded mild steel side frames. Both drum shafts are extended to one side and carry warping drums. Each main spur wheel rotates with the shaft and carries a Ferodo-lined friction cone, providing the drive to the drum, brought into engagement by twin thrust screws operated by hand lever. The drums are fitted with band type brakes operated by foot pedals and with ratchet wheels to engage with pawls secured to the base. The power unit is a 46·5 h.p. Pelapone diesel engine with isolating clutch and triplex roller chain drive to the winch and raking mechanisms. The chain is fully enclosed and all gearing is protected by guards. A steady load of 3½ tons can be lifted by either drum and the hoisting speed of the winch is 105ft per minute.

The 2½-ton drop hammer is designed for driving piles up to 16in in depth and is arranged to occupy the minimum of headroom. The head is recessed to receive the hammer rope thimble secured by a bolt passing through the body. The hammer is held in the leaders by back cods forming part of the cast body and two T-headed bolts. A hole is provided near the lower end of the hammer for a helmet sling.

The total weight of the plant is a little under 20 tons and a low-loading vehicle of this capacity with a "well" length of 20ft is required for transport. Loading is carried out by sliding the plant sideways on to the trailer platform, where it is jacked up on packing timbers and the rollers removed. The latter are carried alongside the frame in brackets provided for the purpose.

The pile frame is equally suitable for use with steam equipment, but the boiler must then be transported separately. Steam hammers up to size No. 9B3 McKiernan-Terry and 3-ton single-acting may be used and the base will accommodate a size No. 4N double-drum steam winch and No. 20 Spencer-Hopwood boiler. Provision has been made in the design of the base for fitting rail wheels as an alternative to roller mounting. A 10ft pile pitching extension to the superstructure can be provided for use when pitching and driving steel sheet piling in panels.

Frame Lowered for Transport

Turbine-Diesel Motor Torpedo Boats

HER MAJESTY'S Motor Torpedo Boats "Bold Pioneer" and "Bold Pathfinder," are the first motor torpedo boats to be powered by gas turbines in combination with diesel engines. The "Bold Pathfinder" has been accepted into the Navy and the second vessel is expected to enter Her Majesty's service next month.

Both ships are fitted with gas turbines, built by Metropolitan-Vickers Electrical Company, Ltd., and developed from the "Gatric" engine which has operated so successfully in M.G.B. "5559" in 1947. The main machinery has been installed by the shipbuilders. In peacetime each boat will carry a complement of two officers and sixteen ratings, and will be armed with four 21in torpedo tubes and one small gun.

Although largely sister ships, the boats differ in details of the machinery installations occasioned by the difference in hull form. The "Bold Pioneer," which was launched in August, 1951, from the Cowes, Isle of Wight, shipyard of J. S. White and Co., Ltd., is of hard chine form and has the following dimensions:—Length extreme, 121ft; length between perpendiculars, 116ft 3in, and beam, 25ft 6in. The "Bold Pathfinder," built at the Portchester yard of Vosper, Ltd., and launched in September, 1951, is of round bilge form, and has a length extreme of 122ft 8in, a length between perpendiculars of 117ft, and a beam of 20ft 5in.

The Future of Plastics in Engineering

By J. E. GORDON, B.Sc.*

This fourth annual lecture of the Plastics Institute was read by J. E. Gordon at the Institution of Mechanical Engineers on November 13th. The author discussed the subject in broad terms, and he began by suggesting that, as a change from wood to metal was a characteristic of the Industrial Revolution, this country should seize the leadership in the new revolution which might follow from the use of plastics in place of metals. He then went on to review present and future developments and applications of plastics, which part of the lecture is abstracted herewith.

I THINK that to some extent present-day engineers have built for themselves a sort of age of "Meccano." That is to say, they think in terms of fabricating all kinds of structures from sheets and angles and so on. This leads to a very inconvenient division of labour, for it is the duty of the metallurgists to produce these sheets and angles, after which they hand them over to the engineer, who builds whatever he can from the "Meccano" parts available. Although many engineers would deny it, I think that this way of thinking has become very deeply ingrained in the engineering outlook, and it is going to take a great deal of hard work to get rid of it. Of course, for many purposes the "Meccano" system is very convenient, but I would suggest that a limit of development along those lines is almost in sight. For one thing, it is not really possible to design structures of the highest efficiency, and for another the process is not really suited to cheap production.

I remember during the war serving on a committee which was intended to encourage the use of plastics in aircraft structures. We circularised the leading aircraft designers and asked them what properties they would like to have in a plastic for aircraft construction. Without exception the replies indicated that they would like a material very like duralumin, but rather better, if possible, which would be used in just the same kind of way. Now, I do not think that it is technically possible to produce a "plastic metal," and if it were, it is difficult to see any object in doing so.

It is perhaps the combination of the two factors, high efficiency and cheapness, which is, I hope, going to enable me to make some real advances in engineering. Because, with this "Meccano" system it is convenient to make rectangular objects, the engineer perhaps assumes that rectangular shapes are ones which it is desirable to make. One does not find many rectangular structures in Nature, and I think that it could be interesting to examine some typical products and to see whether, if there were no manufacturing limitations, some other shape might not be better in every way.

There is another aspect of the problem. It suits our present system of dividing labour and responsibilities for one man to design the structure and for others to add the wiring, plumbing, and the internal and external finishes more or less as afterthoughts. In plastics, of course, we have the possibility of combining all these things into one integrated structure with great improvements in cost and efficiency. However, the amount of human co-ordination required is certainly frightening.

This question of the efficiency of shape and function is a very real one. Engineers tend to compare materials by simple mechanical properties, such as tensile strength, and in a "Meccano" structure this is generally fair and correct. In some aircraft structures we do tend to find that this is not at all an adequate criterion. You compare, say, duralumin and durestos simply as materials; you must come to the conclusion that durestos is only about half as efficient as duralumin. On the other hand, since, by being cunning, you can make structures from durestos which are about as efficient as dural ones, it follows that the efficiency of shape in the plastic structure must be something like twice as high as that of the "Meccano" component. I feel sure that this principle has a much wider application than merely to aircraft, but it is difficult to get designers to accept it.

The prospect of putting really large loads upon apparently fragile plastic structures feels subjectively wrong. Even when one has worked upon the subject oneself for quite a long time and when one is familiar with the calculations and the stresses involved, emotionally one feels "It cannot possibly take such loads." Of course, there are many failures, but upon the whole these devices do take the loads expected of them and generally nobody is more surprised than the designer when they do. We have to demonstrate that this subjective feeling is wrong.

However this may be, the mechanical properties of our plastics are, of course, important. Although for many purposes we have quite adequate strength and stiffness already, there are quite a number of applications where we should dearly like much better materials.

For a long time to come we shall have to depend upon reinforced plastics for high-strength applications. At present we have only glass and asbestos as relatively inert and strong reinforcements. It may very well be that there are other fibres which exist or can be made. Both silica glass and crocidolite asbestos seem to promise at the least the possibility of much higher strengths. Stiffness is just as important as strength in many structures, and it has long been one of the principal defects of plastics that their stiffness with regard to metals has been too low.

Fairly recently it has been found possible in the laboratory and on a small scale to make reinforced materials with a really sensational improvement in stiffness. Unfortunately, it has not so far been possible to combine the increased stiffness with the increased strength. However, I am quite hopeful that we shall be able to do so before very long.

It is of no value having a more efficient material unless you can use less of it. This means that the various thicknesses will be greatly reduced and we shall encounter buckling troubles. There are, perhaps, two ways of avoiding this difficulty. The first is to introduce some kind of lightweight stabilising material. There are a number of these; the most attractive seems to be the kind which can be poured into a cavity and will foam and set *in situ*. At present there is, so far as I know, only one type of material of this kind; that is the "Sebalkyd" class of resin. This is still rather expensive, but its worst defect is that, at the moment of pouring it is extremely poisonous and must be handled with great care. We should very much like to have a cheaper and a harmless material. Whether such a structure consists of a single closed shell filled completely with foam or whether it consists of a "sandwich" in the ordinary sense will depend upon the circumstances of the design.

In many cases, however, I think that it would be preferable to approach the problem in rather a different way, that is by reducing the specific gravity of the material itself. It may be that one reason why wood is so widely used, even to-day, is that its specific gravity is round about the ideal. A timber of twice the present density would be rather an impractical material, yet the densities of most plastics are about twice that of most timbers. I am sure it would very greatly help the design of aircraft structures, at least, if we had a plastic with a specific gravity of about 0·5 while keeping the present specific strength and stiffness properties. The reduction in density would probably have to be achieved by incorporating air voids in the same sort of way as in wood; if we did so, no doubt we should get something like the toughness and the warm "feel" of wood. I confess that I do not know how this is going to be done, but it is surely not impossible.

So far we have speculated about plastic structures as being made wholly of "plastics," but I do not think there is any reason why we should not employ metals in the same kind of fashion as plastics and in conjunction with them. As a simple example, one might have a pressed shell of thin sheet metal filled with a foamed plastic. However, some of the more complicated examples also look promising. It is possible, for instance, to get really first-class adhesion between steel and the durestos class of materials, if the two are moulded together. The coefficients of thermal expansion are similar and the phenolic resin appears to inhibit corrosion in the steel. In this fashion one can make durestos shell structures with steel inserts in the more highly stressed places; the steel sheet need only be cut roughly to shape and the durestos provides protection and a smooth finish, besides helping to stabilise the steel when under compression. In this way we may have some of the best of both worlds, having to some extent the strength, stiffness and low material cost of the steel combined with manufacturing cheapness and good finish of the plastic.

We have to remember that metals are really excellent as materials; they are cheap, strong, stiff and tough. The difficulties arise in shaping them and to some extent in stabilising thin shells. (Hence corrugated iron.) Going a little further in the direction of metal construction, I should not be surprised to see a wide use for the process which has recently been developed at R.A.E., whereby shaped objects are assembled from simple stepped plates of metal. The steps are then filled in with a suitable resin, which can easily be finished to the required form.

Another thing which seems to be needed is a really cheap and satisfactory finish for the low-pressure laminates. Perhaps the "transfer finish" system (whereby the finish is sprayed on the mould and transfers itself to the moulding) may be an answer.

One has to ask "Why do plastics seem to be catching on so slowly in engineering?" The answer is perhaps partly a question of conservatism and partly, I think, that many designers do not realise how much can now be done. Yet I think the main reasons are economic. The manufacturer is frightened, and often rightly frightened, by the high costs of the raw materials combined with the undoubted technical difficulties.

The economic question is a very complex one and must depend upon the type of product which one has in mind. Let us examine a few concrete examples and let us hazard some actual costs. These costs will only be guesses, but perhaps they may be in the right region.

Perhaps I may take the aircraft industry first because I am most familiar with it.

If we consider the airframe of a transport machine, the all-important consideration is weight. A pound of weight saved on the airframe is a pound of extra available payload throughout the life of the machine, and that is worth a very great deal of money. With existing materials it is difficult to promise any considerable saving of weight over a metal airframe at present; relatively small improvements in materials might, however, put the whole question in quite a different light. If that were so, the cost of the material would be quite a secondary consideration. The design and manufacture of a transport aircraft is, however, an enormously difficult and expensive project, and it is very unlikely to be undertaken in plastics until there is ample and successful experience with small light aircraft.

Leaving aside military aeroplanes, this experience is most likely to be gained upon the light "private-owner" type of machine. Now I believe that the cost of building conventional airframes is in the region of 50s. per pound finished weight, the cost of duralumin is about 3s. per pound, the difference being mainly cost of fabrication. (Wood may be a little cheaper, but maintenance costs are perhaps a little higher.) Since the weight of the airframe of a two-seater aircraft will not be less than about 600 lb, one is faced with an expenditure of about £1500 before providing an engine and instruments. It is to be remembered that an aircraft is not a substitute for a car.

* Royal Aircraft Establishment, Farnborough

If one is to reduce the cost sufficiently to justify quantity production the total price must be cut very substantially. Most of this reduction must be made at the expense of the airframe, because the engine and instruments probably cannot be very greatly cheapened. To make the venture attractive, therefore, the target to be aimed at seems to be a structure cost lying between 10s. and 15s. per pound. This might reduce the airframe cost to £300–£400, and take £1000 or so off the cost of the aircraft.

This probably requires a material cost of, say, 5s. to 7s. per pound at the very most, and there are structural plastics available at these sort of prices which are technically suitable. A difficulty arises out of the low wing loadings which are necessary. These lead to low structure loadings and thus to thin panels of material which need to be stabilised, probably by a foamed material. If this is to be of the foamed-in-site type it is going to cost about 15s. per pound, and one needs a surprisingly large quantity of it. Such a project might, therefore, be regarded as just about marginal at present, a relatively small reduction in cost might make it economically attractive. Technically I do not think that there are any insuperable difficulties and there are some considerable advantages. For some time now aerodynamicists have had available wing sections of much lower drag, if only smooth surfaces could be attained ; if we can get these smooth surfaces with plastics we are going to see a much better performance. Again, a considerable part of the cost of running an aircraft arises because the law rightly requires that the complex structure shall be pulled to pieces and examined at fairly frequent intervals in the interests of safety ; in a plastic aircraft this should not be so necessary, as there will be very little to examine ; moreover fatigue is unlikely to be a serious trouble. I do not know if we shall ever see the quantity-produced light aircraft ; but, if so, I think it will have to be made in plastic. Perhaps this is a fairly typical example of the more expensive type of product, where a small reduction in material cost might open up a new market.

If we take the cheaper end of the scale—say, a motor-car—then superficially the present position appears to be much less favourable. One might guess the cost of a car body to be in the region of 4s. per pound, and at this price the existing laminates would seem to be out of the market altogether. On the other hand, one is not so much purchasing weight as strength. If we could replace 18 S.W.G. steel by 0·10in laminate then the weight of the body would be roughly halved and one might afford to pay about 8s. per pound for the finished body. If such a weight could be achieved, then reductions could be made in the engine and chassis and an altogether cheaper car might result.

While a steel body is relatively cheap to make, it is heavy and, because it rusts, its life may well be shorter than that of the chassis and engine. With the new bigger and slower engines, which should last longer, it may be necessary to provide replacement bodies instead of replacement engines.

At 8s. per pound finished weight the existing laminates are still too expensive as raw materials, but if we suppose a suitable cheap material to be available, it is interesting to inquire how the job might be tackled technically.

It is clear that a good deal of redesign would be needed. One of the objections which is often raised to the plastic car body is that it would be difficult to repair. However, we might consider such a body as being moulded in comparatively small panels, not more than 2ft or 3ft square. These panels might be fairly readily detachable and their joins might be concealed by a plated beading. Each panel might comprise the outer finish, the structural shell, much of the inner finish and possibly certain wiring and fittings, all moulded in one operation. Replacement panels might be sold so that a damaged unit could be replaced by undoing a few bolts ; this could probably be a much quicker and cheaper form of repair than the present system of panel beating followed by recellulosing.

Both the materials used and the production processes would need careful thought. For the quantities involved the present low-pressure laminating processes are probably not economic, and it seems probable that pressure moulding with metal dies would have to be used. As the tool cost would be high it would be necessary to obtain a production rate from the dies roughly equal to that obtained in steel presswork at present.

This raises the question of the curing cycle which is likely to be achieved. Judging by American experience, it is possible to reduce the cure times of the glass-polyester materials in heated dies to a matter of two or three minutes, or possibly less. Unfortunately, the glass-polyester materials do not, at the moment, seem to promise low enough material costs. If we want to have a very cheap material we shall probably have to use a phenolic resin. The cure of phenolics by normal methods seems likely to be too slow for a process of this type. At Farnborough, lately, we have been developing an electrical curing system, which gives virtually instantaneous cure, and it seems to hold the promise of giving production rates equivalent to those attained with steel pressings. Incidentally, I wonder whether wings and bumpers in polyethylene would be practicable. They would be very light and virtually indestructible.

Several designers have said to me recently that if they could only obtain a phenolic felted material for less than 2s. per pound, the uses to which it could be put would be virtually unlimited. This, of course, is far less than present prices, but now that we are beginning to see phenolic resins on the market in the region of 10d. per pound and are not without hope of cheap fibres, I do not think that it is by any means an impossible target.

There is an unfortunate circle of cause and effect in such matters which is difficult to break. Because there is no cheap material on the market there is no firm demand for it, and because there is no firm demand there is no supply, for clearly such prices can only be attained with large-scale production.

I have seen something of some of the inquiries which have been held into such supply problems. They usually seem to proceed along lines something like this. A most careful and laborious estimate is made of the sources of supply of the product from various firms and from various countries. A further laborious computation is then made of the present consumption for various purposes. The inquirer then usually finds, to his pained surprise, that the two totals are, nearly enough, equal. Indeed, it would be rather surprising if they were not, for it can hardly be expected that the producer will accumulate great stocks in excess of demand in case a new use for the material is discovered.

While I imagine that there must be few raw materials of which larger quantities cannot be discovered, the more real difficulty probably lies in the delays which accompany the provision of new plant and equipment. It will be hardly believed to-day, yet it is perfectly true that some sixty or seventy years ago it was quite possible to have a steam yacht of a hundred tons or so designed, built and delivered in about six weeks. Apart from the improvements in the art of administration, this seems to suggest that classical engineering is beginning to suffer from a hardening of the arteries. I am afraid that I do not know of any cure.

The provision of shell structures at low cost is one of the things which, I think, that plastics can do very well, given quite a modest reduction in material costs. It is just this making of shaped shells that is so very difficult and unsatisfactory in metals. Apart from the lighter types of shell structures, there seems to be quite a potential opening for piping and containers of all kinds in chemical works, gasworks, oil refineries, and so on. However, the mere fact that it is easy instead of difficult to make such shapes may perhaps lead to the development of quite new kinds of products which have not so far been thought of.

Now all these applications have been in the field of fairly orthodox " rigid " engineering. With plastics we have, for the first time, a really remarkable range of flexible materials, and it may very well be that one of the most interesting prospects will be the opening up of new engineering in flexible materials. There are some obvious uses for flexible piping and so on, but it seems to me that we hardly begin to touch the possibilities of what I might call " pneumatic " structures.

We have heard relatively little in this country about the " air-supported roof," although I believe that it is being quite widely exploited in America. The basic concept is as follows. A very large flexible and preferably transparent sheet of plastic is spread out and " pegged down " at the edges. Two or more small fans are then used to blow the sheet up into a saucer-like roof. Very little pressure is needed and I understand that air locks are often not required. Anybody who has tried to deflate such a device as a pneumatic dinghy will readily understand that small leaks make very little difference. It appears that such domes are quite stable in high winds and can withstand snow loading. If these devices are successful, then they will open up quite a new approach to the whole question of weather protection and we may be able to erect very cheap temporary, or perhaps permanent, roofs over football stadiums, crops, and so on. The effect upon farming in extreme climates, for instance, would be very great.

If we may look still further ahead the prospects for the future are bewildering and perhaps dazzling. Consider, for instance, the possibilities of a really satisfactory photo-catalysed material. One can imagine that such a material might be set by a process akin to three-dimensional photography. Instead of expensive moulds one might feed the necessary optical scanning data into a machine by means of a punched card and thus obtain any shape which we cared to demand.

Again, there is the possibility of a soft piezo-electric material. Now, an animal can be considered as both soft and infinitely rigid, for it can resist a deflecting force, without displacement, by pushing in the opposite direction, consciously or subconsciously. If this were not so we could not stand upright. Nature is not much troubled by Euler. If we had a material which could be made to expand or contract by a small amount by applying an electrical potential the whole approach to structural engineering would be altered.

It would be absurd to pretend that plastics are ever likely to oust metals completely, and it may be that they will always be in a minority as regards tonnage. It is to be remembered that enormous quantities of wood are used to-day, perhaps more than metal, certainly more than was used in 1800. The coming of metals, however, transformed engineering by transforming people's ideas and perhaps it may be that we shall find plastics acting in a similar way as a catalyst for a new Industrial Revolution. The question, to my mind, is whether we are going to take the lead in this process or abandon it to some other nation. I must confess that I find the rather prevalent attitude of dependence upon American development rather disquieting.

It is clear that we must spend more money upon development work and because development work is very expensive it has always been something of a Cinderella to the financiers. Like Faraday, we must say to them : " Sir, you will soon be able to tax it."

Yet money without men is useless, and, as I have said, we must seek to attract the right kind of men. Scientists we must have, of course, but I do not think that we need only or mainly scientists. It seems to me that the trouble with scientists is that they do not recognise that engineering is not really a science ; it would be easy, and rather malicious, to compile an anthology of " howlers " perpetuated by eminent scientists. You may compare Kelvin's *ex cathedra* pronouncement of the impossibility of mechanical flight with Tennyson's " Pilots of the purple twilight, dropping down with costly bales." I think that men who are going to attempt that which many of the pundits declare to be impossible need to have something of the poet in their composition.

Engineering development is not a science, at least, not in its early stages ; it uses science, which is a different matter, just as does medicine. One of the great eighteenth century doctors was said " to have found Medicine a Trade and left it a Philosophy " ; perhaps we need men who will be both adventurers and philosophers in engineering.

Temperature Standardisation at the National Bureau of Standards

(By our American Correspondent)

As a result of the increasing need for reliable temperature measurements at both very high and very low temperatures, the National Bureau of Standards, Washington, D.C., is extending its temperature standardisation programme toward the extremes of the temperature scale. The following notes describe the current work of the Bureau in this field.

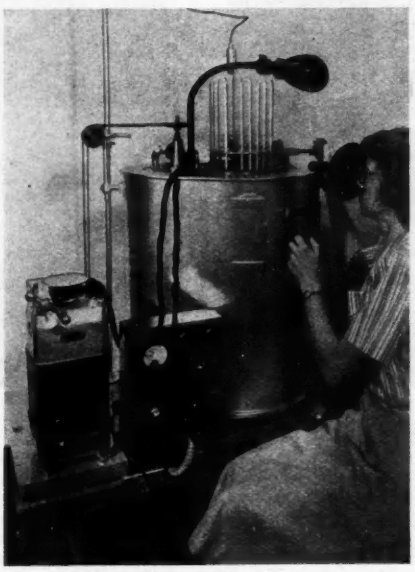
WHILE the accurate measurement of temperature has long been of interest to the research scientist, its importance, particularly at the extreme ends of the scale, has greatly increased with the rapid technical developments of recent years. During this period many improvements in processes for the production of steel, glass, petroleum and other important commodities have resulted from the increased precision that is being attained in the measurement and control of temperature. To provide a fundamental basis for precise temperature measurements, a scale of temperature has been established which covers the range from the boiling point of oxygen to the highest temperatures of incandescent bodies and flames. This scale, known as the International Temperature Scale, is based on six reproducible equilibrium temperatures, of fixed points, to which numerical values are assigned, and upon specified interpolation formulæ relating temperature between or above these points to the indications of standard temperature measuring instruments. The Temperature Measurements Section of the N.B.S., under the direction of Dr. R. E. Wilson, is currently engaged in the development of new temperature measuring instruments and methods of calibration and is conducting research work aimed at further extensions of the International Temperature Scale.

The International Temperature Scale

It may be recalled that the International Temperature Scale was first adopted in 1927 to provide a scale which would conform as closely as possible to the thermodynamic scale proposed many years earlier by Lord Kelvin. The scale which he proposed was based on a relation between the efficiency of a reversible heat engine and the temperatures between which the engine operates, and was independent of the working substance in the engine. Temperatures on this scale are identical with those appearing in the ideal gas law and other thermodynamic relations. By observing the change of pressure with temperature of a constant volume of gas, or the change in volume of a quantity of gas under constant pressure, and applying a correction for the imperfection of the gas, temperatures on the thermodynamic Kelvin scale can be determined. In practice, however, the complexity of an accurate gas thermometer and the difficulty of making highly precise measurements with it are severe limitations on its use.

The International Temperature Scale of 1927 proved useful in providing a stable, uniform and precise basis for obtaining temperatures. However, in the twenty years following its adoption, the increasing precision attained in temperature measurements made it apparent that some revision was desirable in order to make the scale more self-consistent and to improve its agreement with the thermodynamic scale. After consultation with scientists and laboratories in the United States and abroad, the National Bureau of Standards prepared a draft which formed the basis of the document finally adopted at Paris by the Ninth General Conference on Weights and Measures as "The International Temperature Scale of 1948." On January 1, 1949, the Bureau began using the definitions of the 1948 scale, both in its own research programme and in calibrating instruments for other scientific and industrial purposes.

The six fixed points of the 1927 scale were the boiling point of oxygen (−182·97 deg. Cent.), the freezing and boiling points of water, the boiling point of sulphur (+444·60 deg. Cent.), the melting point of silver (+960·5 deg. Cent.), and the melting point of gold (+1063 deg. Cent.). From −190 deg. to +660 deg. Cent., the measurement of temperature was based on the indications of a standard platinum resistance thermometer used in accordance with specified formulæ; from +660 deg. Cent. to the gold point, the platinum versus 90 per cent platinum-10 per cent rhodium thermo-couple was considered standard; and above 1063 deg. Cent. the optical pyrometer was used. The same fixed points, with one slight modification, are specified in the 1948 scale, and the instruments and interpolation equations for obtaining



Testing of Liquid-in-Glass Thermometers

temperatures between fixed points are essentially the same as those previously used. Only two revisions in the definition of the scale resulted in appreciable changes in the numerical values assigned to measured temperatures. One of these was the change in the value for the silver point from 960·5 deg. to 960·8 deg. Cent., which made numerical values of temperatures measured with the standard thermo-couple in the range between 630 deg. and 1063 deg. Cent. somewhat higher, the maximum difference being about 0·4 deg. near 800 deg. Cent. The other change was the adoption of a new value (1·438 cm-deg.) for the constant c_2 in the radiation formula used to calculate temperatures above the gold point as observed with an optical pyrometer. Also, in the new scale, Planck's radiation formula is specified instead of Wien's for calculating these temperatures. Since Planck's law is consistent with the thermodynamic scale even at high temperatures, this change removed the upper limit to the scale formerly imposed by the use of Wien's law.

The International Temperature Scale is now commonly used from its lowest limit, the normal boiling point of oxygen (−182·97 deg. Cent. or 90·19 deg. Kelvin), to the highest temperatures measured. For temperatures below the oxygen point down to about 10 deg. Kelvin, the National Bureau of Standards maintains an auxiliary scale based on the resistance of platinum resistance capsule thermometers, some of which were calibrated using a helium gas thermometer. At the time it was established, this scale was made to agree with the thermodynamic scale as closely as possible. Capsule resistance thermometers are now being calibrated on this scale by the Bureau for laboratories in the United States and in foreign countries. In connection with the maintenance of the International Temperature Scale, the Bureau calibrates the three standard instruments—platinum resistance thermometers, platinum-platinum rhodium thermo-couples, and optical pyrometers—and certifies them for other laboratories. These laboratories then use the calibrated instruments as working standards for the calibration of other temperature-measuring instruments. In addition to the working standards, other thermo-couples as well as liquid-in-glass thermometers and ribbon-filament lamps are certified by the N.B.S. Standard resistance thermometers and thermo-couples are used to determine the temperature of the testing baths and furnaces. Some liquid-in-glass thermometers are also calibrated against standard resistance thermometers and are then used as working standards to calibrate other liquid-in-glass thermometers. Our illustration shows liquid-in-glass thermometers being tested by comparison with one of the Bureau's standard platinum resistance thermometers. For the temperature range from 0 deg. to 100 deg. Cent., the thermometers are immersed in a mechanically stirred water bath. The power input to the heater is controlled by the variable transformer at the left of the bath. The thermometers under test are read with a telescope, and the corresponding reading for the platinum-resistance thermometer is obtained with a Mueller thermometer bridge. Approximately 2500 temperature-measuring instruments, including optical pyrometers, ribbon-filament lamps, resistance thermometers, thermo-couples, and liquid-in-glass thermometers, are certified each year for Federal Agencies, State and municipal governments, industrial laboratories and manufacturers. About 48,000 clinical thermometers, a sampling of a much larger number, are also tested each year for the U.S. Public Health Service and other Federal agencies. As a result of this standardising service, practically all measurements of temperatures above the oxygen point in the United States are based upon the International Temperature Scale as established and maintained by the Bureau.

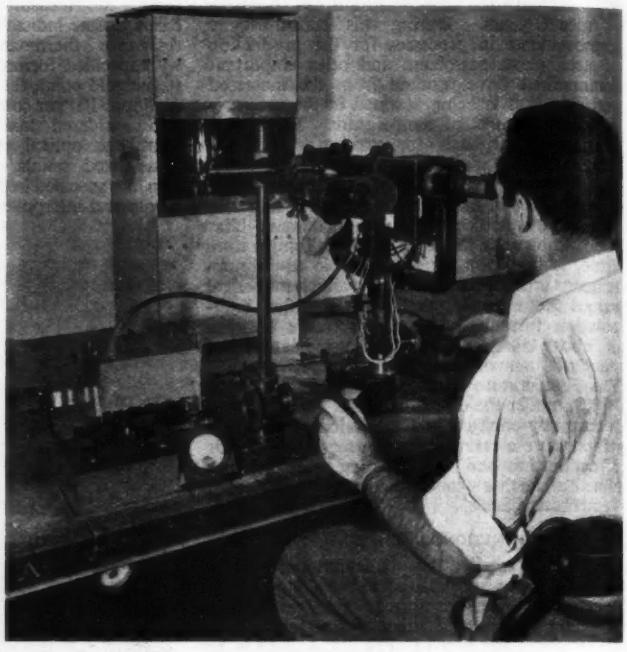
Calibration Procedure

Calibration of a standard platinum resistance thermometer throughout its range is carried out by measuring the resistance of the thermometer at the oxygen point, the ice point, the steam point, and the sulphur point. From these data constants are calculated for the interpolation equation, which gives the resistance of the thermometer at any given temperature in terms of that temperature and the resistance at 0 deg. Cent. The International Temperature Scale specifies that the platinum in the standard resistance thermometer must be annealed and must have such a purity that the ratio R_{100}/R_0 is greater than 1·3910.

The standard thermo-couple, which must contain platinum of high purity and must satisfy certain specific requirements concerning the electromotive force it develops, is calibrated by measuring its electromotive force when one junction is maintained successively at a temperature between 630·3 deg. and 630·7 deg. Cent. (as determined by a standard resistance thermometer), at the silver point, and at the gold point. The reference junction of the thermo-couple is held at 0 deg. Cent. These three values of the electromotive force permit the calculation of the three constants in a quadratic equation which relates electromotive force to the corresponding temperature. The high-temperature calibration of a thermo-couple in the pyrometry laboratory is illustrated overleaf. An optical pyrometer is used to determine the temperature of the thermo-couple hot junction, which is contained in a graphite crucible within a radio-frequency heating coil. The cold junction is kept in an ice bath in the dewar flask to the right of the heating coil.

Optical pyrometers are used to measure the temperature of incandescent bodies by visual comparison of a portion of the radiation from the hot body with that emanating from an incandescent lamp filament. Calibration of such an instrument involves a determination of the pyrometer lamp current which corresponds to a stated temperature. This is done at the N.B.S. by comparing the pyrometer under test with a previously calibrated standard pyrometer, both instruments being sighted upon a ribbon filament lamp which serves as a source of constant temperature, as illustrated. The current-temperature relation for the standard pyrometer is determined by Planck's law of radiation. In this process the pyrometer lamp current corresponding to the gold point is first determined by matching the brightness of a portion of the lamp filament with that of a black body immersed in freezing gold. The calibration is extended above the gold point by using a ribbon filament lamp and sector discs. The temperature of the ribbon filament lamp is first adjusted until its brightness, when viewed through a given rotating sector disc, is equal to that of a black body at the gold point. From the known fractional transmission of the sector disc the brightness temperature of the lamp itself, without the disc, is calculated by means of Planck's law. The sector disc is then removed and the pyrometer lamp current is increased to obtain a brightness match between the pyrometer lamp and the ribbon filament lamp. When this match is obtained the pyrometer current corresponds to the calculated temperature. In order to be able to calibrate commercial pyrometers below the gold point the calibration of the standard pyrometer is extended to lower temperatures by inserting, in turn, various rotating sector discs between the pyrometer and the gold point black body and observing the pyrometer lamp current required to match the resulting reduced brightness. The corresponding temperatures below the gold point are then calculated from the fractional transmissions of the various sectors and Planck's law of radiation. By the use of sector discs with different angular openings the pyrometer lamp currents for various temperatures on either side of the gold point are determined and a complete calibration is obtained by interpolation.

High-Temperature Calibration of Thermo-Couple



Calibration of Optical Pyrometer

The Ice Point

The most commonly used fixed point in thermometry is the ice point, which is defined as the temperature of equilibrium at a pressure of one atmosphere between ice and air-saturated water. In practice this definition is difficult to realise exactly because all impurities except air (the composition of which is not specified) must be absent and because complete saturation by air is difficult to attain. Fortunately, the effects of these factors are small except in measurements demanding the highest precision. When the ice point was first defined, the ice bath, made of finely divided pure ice and distilled water exposed to the atmosphere, was assumed to be sufficiently accurate to fix the ice point temperature within 0·001 deg. Cent. Later, however, when an accuracy of 0·0001 deg. Cent. was desired, a more reproducible standard became necessary. The Bureau therefore began an investigation of the triple point of water, defined as the temperature at which ice, liquid water and water vapour are in equilibrium. As a result of this work a special piece of apparatus known as a triple-point cell was designed for the determination of the triple point, and the triple point is now used by the Bureau instead of the ice point for high-precision measurements. The triple-point cell, which is illustrated on page 737, consists of a cylindrical glass container having a coaxial re-entrant well for a thermometer. Very pure air-free water is sealed in the cell, partially filling it. The technique adopted at the N.B.S. in preparing a cell for use is to freeze a mantle of ice along the thermometer well. This method further purifies the ice adjacent to the thermometer well. A thin layer of ice is then melted to provide the interface between pure water and pure ice, both of which are in contact with the vapour phase. Experiments carried out in 1942 showed that the triple point was very close to 0·0100 deg. Cent. and that its value as obtained with the triple-point cell was reproducible to within approximately 0·0001 deg. Cent.

The Steam Point

Next in importance to the ice point, or triple point, is the steam point, defined as the temperature of equilibrium between liquid water and its vapour under the standard pressure of one atmosphere. The Bureau has conducted considerable research in an effort to make this temperature as reproducible as possible. While the steam point may be determined in a boiling-point apparatus left open to the atmosphere, corrections for atmospheric pressure, which is constantly changing, must be made, and precision is difficult to obtain in this way. The Bureau has therefore developed a controlled pressure system, employing a precision manometer, which has been used for the calibration of standard platinum resistance thermometers. A closed boiler, into which six thermometer wells extend, is connected to the precision manometer by a tube filled with helium. The manometer, which is situated in a temperature-controlled pit, consists of a mercury column with a mercury cell at each end mounted on gauge blocks. Adjusting the difference in the heights of the two columns of gauge blocks establishes the desired pressure, which is transmitted by means of the helium to the closed boiler. In order to determine the heights of the mercury surfaces in the mercury cells, the electrostatic capacity between the mercury surfaces and insulated metal plates above them is made a part of a beat-frequency oscillator circuit. After the manometer is adjusted, a change in pressure is detected by a change in the beat frequency. The pressure can be returned to its original value by the manual adjustment of a small piston in the helium system. With this equipment a change in pressure equivalent to 0·00001 deg. Cent. at the steam point can be detected, and determinations of the steam point made during one day agree within 0·0001 deg. Cent.

The Sulphur and Gold Points

Until recently, standard platinum resistance thermometers were calibrated singly at the sulphur point, using apparatus open to atmospheric pressure. However, as a result of further research, the use of pressure control has now been extended to measurements of the sulphur point. Previously variations in atmospheric pressure had been both troublesome and a source of uncertainty in the measurements, and most of the determinations were being made at night because pressure variations are smaller during that period. The new method uses a closed aluminium boiler having wells for ten thermometers and connected to the precision manometer. This apparatus will make possible a study of the sulphur point as a precise fixed point for thermometry purposes.

The Bureau is now working to develop equipment for the precise determination of temperature on the thermodynamic scale. To aid in this work, a "noise thermometer," developed at the University of Chicago, has been set up at the N.B.S. to measure thermodynamic temperatures. The mean-square voltage due to thermal fluctuations in electron density in a resistor—usually referred to as "thermal noise"—is a function of the thermodynamic temperature of the resistor. By comparing the noise voltages across two resistors at different tem-

peratures, it is thus possible to determine the ratio of the temperatures of the resistors. The first measurements will be made of the temperature of the gold point, which is important both for the thermo-couple and optical-pyrometer ranges of the International Temperature Scale.

Temperature-Measuring Instruments

The development of improved temperature-measuring instruments is closely related to the work on the temperature scale. Thus, in connection with the maintenance and improvement of the International Temperature Scale in the temperature range from 630·5 deg. to 1063 deg. Cent., investigations have been made to determine the effect of annealing on the electromotive force of standard platinum versus platinum-rhodium thermo-couples. This study included a determination of the effects of different annealing temperatures, cooling rates, and atmospheres in which the thermo-couples were cooled. It was found that some of the

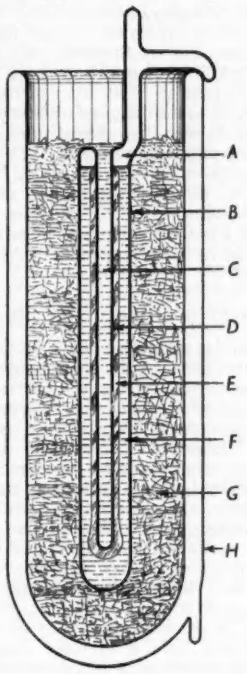


Diagram of N.B.S. Triple-Point Cell

electrical properties depended upon the rate of cooling and that not only chemical purity but also mechanical strains must be controlled for maximum uniformity.

Research is now being conducted to find a better material to substitute for the alumel wire of a chromel-alumel thermo-couple. When used under conditions encountered in exhaust gases in aircraft engines, the alumel has been found to become brittle and to fail after a relatively short period of operation. Available substitutes for alumel which appear likely to withstand the vibration and corrosive atmosphere are being investigated to determine their performance under these extreme conditions.

Future plans call for the construction of comparator furnaces to study the performance of standard platinum resistance thermometers and thermo-couples between calibration points. As the International Temperature Scale is based on a relatively small number of fixed points, it is necessary to investigate the standard temperature-measuring instruments between these points and to evaluate the precision with which they can be used over the intervening ranges. In this way the Bureau hopes to ensure that standard calibrated instruments of a given design indicate the same temperature at any temperature within their range. Research work is also being carried on in connection with the testing of clinical thermometers. Recently, in order to develop an improved specification for clinical thermometers, a study was made of the change with time in the calibration of a group of thermometers which had been given a special stabilising heat treatment by the manufacturer. Earlier specifications had required that clinical thermometers be aged by three months' storage before calibration so that the volumes of the bulbs would have time to become constant. The results of the work at the N.B.S. showed that the "artificial ageing," which requires less than a week, is fully equivalent to the earlier method.

A significant advance in the measurement of extremely high temperatures was the recent development of an iridium versus iridium-rhodium thermo-couple. Because of the high temperatures—up to about 3800 deg. Fah.—which prevail in the primary burning zones of turbo-jet and ram-jet combustion chambers, conventional temperature-sensing instruments are not suitable for use in these applications. In preliminary studies, the new thermo-couple has been found to withstand both the thermal and mechanical stresses incident to combustion-chamber operation, and heat-resistant supporting tubes and insulators are now being developed so that the device can be used in flight.

At very low temperatures (below 50 deg. Kelvin) thermometry research at the Bureau at present has two major objectives: the determination of thermodynamic temperatures by means of a gas thermometer and the development of convenient, sensitive and reproducible secondary thermometers which can be calibrated by means of the gas thermometer. Since the development of a highly accurate gas thermometer for this purpose requires painstaking and time-consuming precision, the work on the secondary thermometer is being pursued concurrently. Resistance thermometers constructed of the semi-conducting elements silicon and germanium have proved to be extremely sensitive; in some cases the resistance has been found to change more than 50 per cent per degree. While satisfactory reproducibility still remains a problem, the results of initial tests have been quite promising.

Statistical Methods and Operational Research in Transport*

By F. A. A. MENZLER, C.B.E., M.Inst.T.†

There are many transport problems for which it would be impossible to obtain direct numerical data in the form of routine figures or even specially compiled statistics collected through routine channels. One cannot establish by such means the household or individual pattern of local travel; or the effects of vehicle design on the loading and unloading of bus passengers; or the reactions of the 8ft bus on traffic flow in the streets. Here we enter the realm of "operational research." There is much unnecessary mystery about this particular application of the scientific approach to the problems of management, which has often been practised unconsciously by many who would be surprised to learn that they have been doing so. During the war the use of scientific methods of analysis and unbiased observation, in order to bring about the most effective employment of men and equipment under service conditions, ultimately gained complete acceptance, and was aptly described as "operational research." Its rise, with the dignity of a title, has to a large extent been rendered possible by the development of the newer statistical methods, including the techniques of sampling. Because the observations arising from operational research are usually statistical, it is convenient to discuss the subject in a statistical context. Nevertheless, as has been implied, such researches are scientific in a wider sense, and need the association of the scientist as well as the statistician with the operator or engineer in the analysis of the problem and the organisation of the project.

Size of a Sample

My first practical example of statistical methods illustrates the danger of settling the size of a sample in the light of untutored reason. Taking samples is widespread and, like working out averages, almost instinctive. It is practised in daily life—more often than not unconsciously—and, because it seems to represent little more than commonsense with an eye to economy of effort, many intelligent users of figures think that it is just a matter of taking 1 in 10, or 1 in 100, or even 1 in 1000 as convenience, staff resources, and the whim of the moment may dictate. Actually, for several decades, theory has been worked out to enable the size of the sample to be settled beforehand by reference to certain criteria. Thus, it was desired to test the physical condition of a certain piece of equipment of which several thousands are in daily use in London Transport. In real life it is commonly impossible to go to the extreme of examining periodically every item of equipment. In this instance, a few had been discovered to be defective and, in an attempt to gauge the prevalence of the defect, a test was made by examining a dozen specimens selected at random from the whole of the equipment; all twelve were found to be in order. When statistical advice was sought, however, it transpired that there was about an even chance of a sample of twelve revealing no defectives when the overall proportion defective was, in fact, as high as 5 per cent. Clearly the sample was much too small. Its size should have been fixed by reference to two considerations: first, the proportion of defective units which could be tolerated among the whole of the equipment and, second, the risk that could be run of getting an apparently satisfactory answer from the sample in spite of an unacceptably high proportion of the equipment being faulty. The risk that can be run must, of course, be settled in the light of the particular circumstances of each case; but it is a commonly accepted rule that one can take a 1 in 20 chance of being wrong in such tests. After all, these are fairly long odds. In the present example, the tolerable proportion of defective units had to be low, say, 1 in 200 in the total number of units. On this standard, it can be shown that, if the risk to be incurred is to be only 1 in 20 of finding all the sample units serviceable on inspection, the sample must be one of at least 600 units. Thus, the size of the sample is not an exercise in "hit or miss." No figure-mindedness of the arithmetical kind, even when allied to practical commonsense, can determine its appropriate size. It is obviously unwise, and may even be dangerous, to use sampling methods uncritically. Yet it is a common habit to take samples without knowledge of the limits of error involved, or of the risks which are being incurred that these limits may be exceeded. This is an act of blind faith in the efficacy of sampling which is perhaps hardly appreciated by many who are suspicious of modern statistical techniques, but who often accept without question the results of uncritical or perhaps unsconcious sampling.

Interpretation of Statistics of Failures

In any sizable transport undertaking, weekly or other periodical statistics will presumably be kept of such happenings as failures of different kinds of equipment—it may be timing chains or fuel-injection pumps on buses, or tyres. The weekly or even monthly figures, though complete, are in fact only samples, for short periods of time, of the long-term experience. It follows that the theory of sampling is applicable to the systematic interpretation of such statistics. There will be continuous efforts by the engineers to improve the standard of maintenance and, by this and other means, to reduce the number of failures. The purpose of the statistics is to keep a check on what is happening so that the effect of any remedial measures may be seen or, alternatively, to ensure that prompt action is taken to counter the effects of the intervention of some possible new cause of failure. Comparisons are commonly made with the figures for the corresponding week (or other period) in the previous year in an attempt, however crude, to eliminate the effects of seasonal influences. When plotted on a chart, the figures normally exhibit a disconcertingly zig-zag pattern, and the smaller the numbers the relatively wider are the fluctuations. The engineer will often chart also the so-called "moving average," based on the average number taken over, say,

* Institute of Transport, November 17th. Abstract.
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the last thirteen weeks. This process gives a good bird's-eye view of the underlying trend, and shows up more clearly any seasonal pattern in the numbers of failures. But the moving average slurs over the features of the current weekly experience. How can the zig-zag weekly figures be systematically interpreted to give the engineer the information that he wants, viz. an assurance that any apparent change in level, up or down, is significant? Without such guidance, a false conclusion might be drawn about the effect of some particular course of action or, as often happens, time and effort might be wasted by all concerned in seeking for explanations of what may be no more than quite normal fluctuations, inherent in the small numbers involved.

Table I shows weekly figures of failures of timing chains on buses in 1950 and 1951, during which the number of London Transport buses concerned was substantially constant.

TABLE I—*Timing Chain Failures*

Week	1950				1951			
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1	3	1	4	3	—	2	1	2
2	2	4	1	—	5	6	3	3
3	2	1	3	5	5	5	4	3
4	5	3	—	6	4	2	1	7
5	4	5	2	2	2	2	3	2
6	2	4	8	1	1	4	4	4
7	4	3	4	1	3	3	8	1
8	6	2	3	2	1	4	7	4
9	5	4	5	6	2	9	5	—
10	5	5	3	1	1	1	5	5
11	2	6	3	1	1	8	2	6
12	2	3	4	3	4	1	2	3
13	—	4	1	3	4	6	3	4

The numbers are small and, if plotted on a chart, exhibit the familiar zig-zag pattern. How can such vagaries be safely interpreted? Should it, for example, have been a matter for concern that, in the last week of the second quarter of 1951, the number of failures was six compared with only one in the previous week, and with four in the corresponding week of 1950? Suppose that, in order to keep check on the experience of 1951, it had been desired to put to the best use the experience of failures gained in 1950. At first sight, the weekly movements in the numbers of failures during 1950 do not appear to conform to any regular pattern. If, however, they are grouped as shown in Table II, a definite pattern is seen to emerge.

TABLE II—*Timing Chain Failures in* 1950

Number of failures per week	Number of weeks with that number of failures
0	3
1	8
2	9
3	11
4	9
5	7
6	4
7	—
8	1
	52

The distribution of the number of weeks in which given numbers of failures occurred approximates to a well-known symmetrical curve. Under certain conditions, the greater the volume of such data, the closer would be the approximation to complete symmetry. This particular symmetrical curve, known as the "normal curve," has a long history and its properties are fundamental to serious statistical work. The essential point for present purposes is that a curve of this kind can be shown to represent with sufficient accuracy observations of events which are the result of the inter-play of random and uncontrollable influences. For example, Table III shows the result of fifty-two successive experiments in each of which ten coins were tossed and the number of heads recorded.

TABLE III—52 *Tossings of* 10 *Coins*

Number of heads	Number of times that number of heads was recorded
0	—
1	1
2	2
3	6
4	11
5	13
6	10
7	6
8	2
9	1
10	—
	52

The distribution shown above has the same general shape as the distribution shown in Table II and, like it, approximates to the "normal curve." The significance of this parallelism with the experience of timing chain failures is that, in the case of coin tossing, there is no *a priori* reason for expecting a head to turn up rather than a tail, each result being the net effect of the interactions of a number of random influences. It can be argued, therefore, that if the variations in the numbers of failures follow the "normal curve" reasonably well—as they do—they, too, are due to a combination of chance factors and no particular new or special factor is likely to be operating. The weekly fluctuations can then ordinarily be regarded as no more than the inherent variations in the figures due to the happily small numbers of failures involved, and the interactions of a multiplicity of factors which cannot be isolated or controlled.

To put the matter more concretely, on the assumption that the figures for 1950 in Table II (which give an average of approximately three failures per week) follow the "normal curve," it can be shown that in the long run the numbers of failures might be expected to exceed six in one week in twenty-five, without necessarily giving the engineers cause for anxiety. In both the seventh and eighth weeks of the third quarter in 1951, however, the numbers of failures were eight and seven, respectively. In the light of the experience in 1950, the odds against the figure of six being exceeded in two consecutive weeks would be about 600 to 1, and the presumption would be that some abnormal influence adversely affecting this item of equipment had in all probability been at work. This proved to have been the case. On the other hand, the odds, in this case, against there being no failures in a particular week are 20 to 1, and in two consecutive weeks 400 to 1. If, therefore, two consecutive weeks showed no failures, there would probably have been a significant improvement which would be reflected in due course in a lower average number of failures. At the particular standard of maintenance reflected in an average of some three failures per week, fluctuations up or down between the limits of 0 and 6 would probably have no real significance; but while, within these limits, a rise in the number of failures would not justify "witch-hunting," neither should a fall afford grounds for self-congratulation.

Similar methods are extensively employed by the engineers at London Transport as an aid to the current scrutiny of failures of some eighty separate items of equipment on the buses, the "limit lines" being settled with statistical advice. The conception of a "normal" level of failures, implicit in the use of limit lines, must not be interpreted to mean that they are a substitute for skilled engineering judgment. The methods described must be regarded rather as a systematic aid to the engineer in helping him to decide whether or not special inquiry is called for. They also have the positive advantage that they may do away with often fruitless inquiries of the type: "Why has the number of failures doubled in a week?" with all the waste of time and energy that may be involved. The use of limit lines should not, however, lead to an attitude of complacency on the part of the engineer, who must always be actively concerned to reduce the absolute level of failures.

Stratified Sampling

The study of vehicle "accidents," i.e. damage to vehicles requiring repair, presents problems similar to those arising in the case of failures and delays. The element of chance is evident, revealing itself in the wide variability of the numbers of accidents in successive periods of time. It was recently desired, for instance, to compare the accident rates for buses of different types, and a sample was taken of a year's accidents of all kinds, major, minor, and trivial, in a very large fleet of the order of 7500 vehicles. Such a sample could have consisted of a straight sample of all accidents; of a sample of all the accidents arising with buses at a sample of garages; or of all the accidents for all garages during sample days, i.e. a sample in time. At first sight, it seemed that it would be sufficient to take a simple sample of 1 in 10 or 1 in 20. But, because of differing traffic conditions, the accident risk is likely to be different on Mondays to Fridays, Saturdays and Sundays, respectively, and a straightforward random selection could have resulted in over-representation of Saturdays and Sundays, particularly in view of the numbers involved. A sample based on garages would have been disturbed by differences in the traffic conditions prevailing on the services operated from the chosen garages and on the services generally. Next, there are daily variations during the Monday to Friday period. It was, therefore, desirable that the numbers of Mondays, Tuesdays, &c., chosen should be the same. Then, again, weather may exert a direct influence on the accident rate. As the general state of the weather tends to persist for periods of more than one day, it is desirable to avoid the selection of successive days. It was in the light of such considerations that a sample of thirty days from the 260 Mondays to Fridays in the year under review was selected, with a sequence of every ninth Monday-to-Friday, week-day, e.g. Monday, Friday, Thursday, Wednesday, Tuesday, Monday, &c. Somewhat similar methods were used to select the requisite six Saturdays and six Sundays. This planning of the sample in groups is known as "stratified sampling." It is an illustration of the need for giving thought to the design of observation which, it will later be seen, has special relevance in the case of operational research. The London Travel Survey—which was sponsored by London Transport to establish the pattern of travel in Greater London—required a more elaborate scheme of stratified sampling, of which a full account is given in the Appendix to the published volume.

Examples of Operational Research

So far, in this discussion of accidents, attention has been confined to the information afforded by existing accident records. Questions arise, however, which cannot be answered from accident records alone, because some vital piece of background information is lacking. An analysis of accidents to passengers, recently undertaken by London Transport, started as a comparatively straightforward statistical exercise, involving the classification of accidents according to the sex and age of the passengers involved, the time of day, the type of vehicle, and so on. Some boarding and alighting accidents occur at stops, others at traffic lights, and when the bus is slowed down or stopped in traffic. Prima facie it is more dangerous to join or leave the bus while it is on its way between the bus stops, but the relative hazards cannot be deduced from the mere knowledge that 20 per cent of boarding and 32 per cent of alighting accidents occur away from bus stops. By actually observing the numbers of people who get on and off at the various possible places—what the actuaries would call the "exposed to risk"—it has been established that it is at least three times as dangerous to board or alight from a bus away from a proper stop as it is to do so at one. Only by relating accidents to a measurable feature of passenger behaviour, viz. boarding and alighting habits, could the problem be tackled. With this example, it will have been noticed, the statistical examination of routine accident data proved insufficient, and the observational method of operational research had to be used as well.

Passenger Habits.—Other "passenger habit" investigations by means of operational research have included the use made in buses of stanchions, of used ticket boxes, of the front half-drop windows, of the facilities for carrying passengers' luggage, and of destination indicators. The last-mentioned study is of particular interest as it would have been impossible, by observation alone, to find out what use passengers make of the various route and destination blinds provided. The observers would not be able to tell whether the people they watched were assimilating what they read or, indeed, whether they were merely staring into space. In this case, the "Gallup Poll" technique was invoked and people were asked a number of questions concerning how they find their way about by London bus. In the course of this inquiry, the fact emerged that a substantial proportion rely upon word-of-mouth sources

of information and are mistrustful of notices, maps or posters.

Driving and Fuel Consumption.—The technique of driving buses, in so far as it affects the amount of fuel consumed, is being studied at the present time. The principles on which the tests were designed can be illustrated by describing one of the more simple experiments, made to measure the difference in fuel consumption when a bus is driven at a steady speed and when the speed fluctuates slightly due to intermittent use of the throttle. In this case four experienced drivers and four vehicles, specially selected for consistency as regards fuel consumption, were employed, as being the minimum required for reasonably reliable results. It was also desired to measure the effect of four different vehicle loadings. Speed had to be taken into account, too, for fuel consumption depends upon speed to a greater extent, perhaps, than any other factor. Despite the exercise of the utmost care on the part of the drivers, it could not be guaranteed that the runs with the "steady" and "fluctuating" techniques would be made at exactly the same speed, so that tests had to be made for at least two speeds.

The obvious plan would have been to let each driver drive each bus at each loading, at both speeds, and with both styles of driving. The total number of runs would then have been $4\times4\times4\times2\times2=256$, and the tests would have taken four days. It was desirable, both on grounds of expense and because of possible day-to-day variations in weather, to restrict the test to one day; and since the number of runs had to be reduced, some restriction on the scope of the experiment was inevitable. A plan was needed which gave the greatest accuracy in measuring the effects of the most important factors, viz. the two speeds and the two styles of driving. One way of reducing the amount of testing required would have been to dispense with one of the other factors, such as vehicle load, and to make all the tests at some typical load. It was possible, however, without additional tests, to cover a reasonable range of practical conditions, and to take account of variations in loading as well as of the idiosyncrasies of the four drivers and the four buses. To do this, the tests were arranged as shown in Table IV.

TABLE IV—*Scheme for* 16 *runs : speed* 20 *m.p.h.—Fluctuating Style*

	Buses			
	A	*B*	*C*	*D*
Driver *a*	Load 1	Load 2	Load 3	Load 4
Driver *b*	Load 2	Load 1	Load 4	Load 3
Driver *c*	Load 3	Load 4	Load 1	Load 2
Driver *d*	Load 4	Load 3	Load 2	Load 1

Note.—The same scheme of observation was used for all four combinations of speed and style of driving, viz. :—
20 m.p.h. and fluctuating style.
20 m.p.h. and steady style.
30 m.p.h. and fluctuating style.
30 m.p.h. and steady style.

To minimise the effects of atmospheric changes, the runs to be compared had to be made close together. Furthermore, as the mechanical parts of the buses warm up with use, fuel consumption would be expected to improve steadily during the day so that each run would produce a lower consumption than the last. For this reason, the order in which the speeds and styles of driving were tested was changed each time the drivers changed buses. The experiments yielded four major results, viz. the fuel consumptions corresponding to the two styles of driving at the two speeds; each result being derived from groups of sixteen runs, all four groups being comparable. The results can be summarised by saying that unsteady or intermittent use of the accelerator wastes 16 per cent of fuel at 30 m.p.h. and 10 per cent at 20 m.p.h. Much more information of a useful character can be extracted from the data, which are in a form suitable for the application of a statistical technique known as "analysis of variance," to which reference is made in connection with a later example, concerned with the fuel consumption of buses in service.

How are we to interpret the ordinary service records of fuel consumption, usually presented in the form of weekly or four-weekly returns? The figures will be observed to vary up or down from period to period and the engineer will wish to know the reason; in particular, an increase in fuel consumption will always give rise to anxiety. Has there been any deterioration in the standard of maintenance? Has the adoption of a change of practice or of a particular modification had an effect other than the expected one?

The fuel consumption of a fleet of vehicles is affected by a number of variable factors; some of them are within the control of the operator, others are not. They include: passenger loadings, weather and, in particular, atmospheric temperature, traffic density, mean daily mileage per vehicle, standard of driving (as already seen), composition of fleet, standard of maintenance, and viscosity of lubricating oil. These factors are of varying importance and do not operate to the same extent all the time. For example, in most years, the fuel consumption (in terms of miles per gallon) of London Transport's central bus fleet varies closely with changes in atmospheric temperature. But, at certain seaside resorts, the variations in passenger loadings are such that fuel consumption is greater in summer than in winter; and, even in London Transport, the usual improvement in fuel consumption failed to be apparent during the summer of 1950, when petrol was derationed. This led, of course, to increased traffic congestion owing to the larger number of private cars on the roads. Fuel consumption varies also with the weight of the loaded vehicle, although the relationship is not a direct one, and, moreover, is not the same at different speeds. It is fair, however, to assume that for small changes in weight, such as would result from the addition or subtraction of a few passengers, fuel consumption changes *pro rata* with changes in the total weight including passengers. The recorded fuel consumption figures can therefore be adjusted by simple arithmetic to allow for the effects of variations in passenger loadings. If the relative fuel consumptions of the different types of vehicles are known, allowance can also be made for changes in the composition of the fleet.

No such simple means can, however, be employed to allow for the effects of variations in such factors as mean weekly car mileage for each vehicle or of changes in the weather, the latter including variations in temperature, rainfall, and incidence of fog and frost. To disentangle the varying effects of these factors we must have recourse to other rather more specialised statistical techniques. The problem is a difficult one in that the variables are not independent of one another, but enough has been done to enable us to give tentative explanations—in quantitative terms—of differences in fuel consumption between one year and another. Thus, for the year 1951, the fuel consumption of London Transport's central bus fleet, as reflected in "miles per gallon," was 0·28 (2·9 per cent) worse than it was in 1950. The extent to which the various factors were estimated—however broadly—to have contributed to this increase in consumption is shown in Table V.

TABLE V—*Analysis of Differences in Fuel Consumption during* 1951 *compared with* 1950 (*in terms of miles per gallon*)

Cause	Change in miles per gallon	
	Decrease	Increase
Alterations in composition of fleet	0·07	—
Decrease in weekly mileage per vehicle ...	0·01	—
Decrease in mean atmospheric temperature	0·02	—
Increase in mean hours of rain	0·01	—
Increase in use of lower viscosity engine oil	—	0·07
Other known factors	0·07	—
	0·18	0·07
Net decrease accounted for	0·11	
Unaccounted for	0·17	
Total net decrease	0·28	

It will be seen that so far little more than one-third of the increase in consumption had been accounted for. It was generally accepted, however, that the density of traffic during 1951, the Festival of Britain year, was greater than during 1950, and it was not unreasonable to suggest that the residual increase in consumption was largely due to an increase in traffic density. Through the courtesy of the Road Research Laboratory, which provided us with records obtained from some of its automatic traffic counters, it was found that there was a marked correlation between the fuel consumption of the central bus fleet and the traffic counter records over a period of three years. By a further application of the same technique, it was estimated that the increase in traffic density during 1951, compared with 1950, was sufficient to have caused an increase in fuel consumption equivalent to about 0·12 miles per gallon. The residue not accounted for was thus reduced to 0·05 miles per gallon.

It is often necessary to ascertain the effect on fuel consumption of a modification of some sort or other, initially applied to a small number of buses. Examples of such modifications are a change in the viscosity of the engine lubricating oil, alterations to carburettor or fuel injection pump settings, or a mechanical modification such as a change in the design of the engine silencer. The required information is, of course, obtained by comparing the performance of two groups of vehicles, one embodying the experimental feature, the other being standard. The problem is to design a test which will not be invalidated by the fact that each bus has its own individual characteristics and, in service, is doing a distinctive job. If the number in each group is too small, these variations are likely to disguise any real difference between the two groups, and it can be shown from statistical considerations—now reinforced by experience—that not less than twelve vehicles should be employed in each group. The two groups must also be operated as near as may be under the same conditions of weather, numbers of passengers carried, and traffic on the roads. To achieve similarity of weather conditions both groups of buses, twenty-four in all, are tested concurrently. Substantially comparable traffic conditions and passenger loadings are obtained by operating all the buses on a single route from one garage, with each bus performing, during the course of the test, each of the different duties (known by "running numbers") which go to make up the programme of work scheduled for the route. In this way the experimental design enables the effects of the particular factors under study to be isolated, leaving the effects of other factors to balance out. It would obviously help to eliminate disturbing influences due to the individual characteristics of buses if the experimental feature were interchanged between the two groups of vehicles. But, in some cases, as for example in measuring the effect of a difference in the viscosity of the lubricating oil, this is not possible for practical reasons, and the experimental feature has to be confined to one group of buses throughout the experiment. Sometimes, however, as for example in studying the effect of a change in carburettor setting, it is possible to try out the modification first in one group of vehicles, then in the other, the change-over being effected at, say, weekly intervals. A test which has been planned on these lines is appropriately described as being of the "cross-over" design. In one test, recently completed, the mean fuel consumptions for the two groups of vehicles were 8·78 and 8·56 miles per gallon, a difference of 2·5 per cent. Further statistical examination was needed before this result could be accepted. The individual daily vehicle fuel consumptions which go to make up these average results exhibited wide variations, partly on account of differences between vehicles, and between their various daily duties, and partly without assignable cause. The experiment may be regarded as a sample of a trial made on a very large scale so that the results are therefore only estimates of the true difference between the two groups of vehicles. Thus, an arithmetical difference could be shown by the experiment when there is no real difference. Application of the analysis of variance technique showed that the difference of 2·5 per cent could be accepted as unlikely to have arisen by chance. By a further process it was demonstrated that there was a 20 to 1 chance against the true difference being more than 2·9 per cent or less than 2·1 per cent. Such an

assessment of the results is vital when the adoption of a costly modification is in question. A further result of this application of analysis of variance was that different daily duties yielded significantly different fuel consumptions, thus re-emphasising the importance of the need for careful design of the experiment to ensure that such a factor will not disturb the results.

Organisation of Operational Research

If it is to be successful, the practice of operational research presents some special problems of organisation and psychology to which it is desirable briefly to allude. At London Transport it is customary for operational research projects to be sponsored by suitably composed teams working under the ægis of the Research and Development Committee, a practice which has secured fairly general acceptance of the operational research approach and made for mutual confidence and understanding. The client in the shape of the using department generally provides the chairman who is ordinarily of officer status. Representatives of departments with adjoining interests are also included, while the development and research department is usually represented by a scientist and a statistician, one of whom may serve as secretary. In this way, the scheme of observation is framed so as to take full account of both theoretical and practical considerations and the "client" does not feel that some stranger is "telling him how to do his job." The problem is fundamentally psychological. If the scientist or the statistician is determined to have his kudos, there will be inevitable "sales resistance" from the practical men who bear the heat and burden of the day. Those who wish to contribute to this all-important branch of scientific work must be prepared to submerge their individualities and practise a sort of protective mimicry: the less intrusive their presence, the greater will be their contribution.

African Engineering News

(By Our South African Correspondent)

Railway Progress in the Union

A report on transport progress in the Union of South Africa was recently given by the Acting General Manager of the South African Railways, Mr. D. H. C. du Plessis, in an address to the South African Federated Chamber of Industries, from which the following information has been abstracted. An advance in railway goods traffic from 38,800,000 tons during 1939–40 to 65,169,000 tons during 1951–52, that is, by 68 per cent in twelve years, is an indication of the expansion of traffic for which the railways have had to make provision. In the space of these twelve years, goods traffic increased by 26,300,000 tons, while the total for 1951–52 exceeded that for the previous year by 3,036,000 tons, an increase of 4·9 per cent in one year. The surface area of South Africa and the topography of the country, plus the entire absence of navigable waterways, have combined to make the railways particularly important as the instrument of national development. Railway transport is the only answer in the foreseeable future to the problem of long-distance heavy haulage, in a country where coal is found only in the interior and where such commodities as maize, wheat, manganese, cement, chrome, manufactured products and many others have to be hauled hundreds of miles. The railway system has a route mileage of 13,393 and feeder road motor services comprising just about double the route mileage of the railways.

A complementary feature of the improvement and development programme at present in progress is the acquisition of new rolling stock and engine power. At the end of the 1945–46 financial year, standard gauge engines and electric units in service totalled 2425, with an aggregate tractive force of 76,554,000 lb; on March 31, 1952, there were on the establishment 2609 standard-gauge engines and electric units, with a total tractive force of 85,811,000 lb. On March 31, 1946, the railways had 62,383 goods vehicles; by last March the number had been increased to 82,125, an increase of 19,742 vehicles, or 32 per cent. At the present moment, the Railway Administration has 445 locomotives on order—335 steam and 110 electric—plus 9599 standard-gauge trucks. Only three of the electric units on order have been placed in service. The engine-power position, due to delays in delivery, is not satisfactory, but an improvement is hoped for towards the end of the current year, and a further substantial improvement early next year. The value of orders placed for locomotives exceeds £22,000,000.

Annual Report of Electricity Supply Commission

In the annual report of the Electricity Supply Commission (ending December 31, 1951, but containing an outline of activities up to April 30, 1952), it is shown that whereas the revenue rose by 15 per cent to £10,955,565, production costs rose by nearly 16 per cent to £11,102,484. Thus the year's operations resulted in a deficit of £146,919. Working costs were increased by capital charges on the cost of plant and equipment and coal. During 1951, the Commission sold 7456·5 million units of electricity, an increase of 7·9 per cent over the 1950 figure, but despite all efforts to increase output, the demand for power, created by the rapid expansion of the country's mines and industries, still exceeded supply. The report gives details of the erection of eight new power stations. Capital expenditure over the next six years will amount to £103 million. Restrictions imposed on maximum demands, but not upon the number of units which may be taken, resulted in a substantial improvement in the loading of the system during the period under review.

Plant commissioned during 1951 included a 40MW set at Congella power station and a 33MW set at Vaal. A 7·5MW turbo-generator and two 55,000 lb per hour boilers were commissioned at West Bank No. 1 power station, East London. Altogether, fifty-nine boilers, ranging from 75,000 lb to 580,000 lb per hour of steam and thirty-six turbo-generators, with a total capacity of 1103MW were on order or under erection at the year's end. Since then, four 400,000 lb per hour boilers and one 60MW turbo-generator have been ordered for the new Wilge power station, and tenders for a second 60MW turbo-generator are under consideration. The aggregate installed capacity in the Commission's power stations at the end of last year was 1595MW, an increase of 81MW over the corresponding figure for the previous year. Plant under erection or on order will bring the total to 2638MW. New power stations now under construction are listed herewith.

Hex River.—This power station at Worcester is planned for seven 200,000 lb per hour boilers and five 20MW turbo-generators. Non-delivery of essential materials delayed the commissioning of the first boiler and turbo-generator until June this year.

Salt River, No. 2.—This station is planned for eight 260,000 lb per hour boilers and six 30MW turbo-generators. Two boilers and one turbo-generator are expected to be in operation by the middle of 1954. The estimated cost of the initial installation, including civil works, is £5,464,100.

Swartkops.—This power station will operate in conjunction with the municipal power station at Port Elizabeth. Orders were placed in 1950 for two 210,000 lb per hour boilers and two 20MW turbo-generators, and the first set is expected to be in service during the latter part of 1953. At this stage, the cost of the plant and station is estimated at £3,142,000. It is designed for three 20MW turbo-generators and thereafter 30MW sets as required.

Taaibos.—Taaibos power station is on a site adjoining Clydesdale colliery, and will supply additional power to the goldfields and industry. It will be connected with the Vaal and Vierfontein power stations and will be the centre of a 132-kV transmission system. It is now hoped to start construction of the main station building soon, and the first turbo-generator should be ready for service during the second half of 1954. Orders were placed in 1950 and 1951 for the main installation, comprising six 580,000 lb per hour boilers and six 60MW turbo-generators, at an estimated cost of £15,959,000, including civil engineering works.

Umgeni.—Four 180,000 lb per hour boilers and two 30MW turbo-generators are on order for the Umgeni power station, near Pinetown. The first set is expected to be erected towards the end of 1953, and the second early in 1954, the cost of the development being £4,918,288. Ultimate plans provide for a further twelve boilers and six turbo-generators of similar capacity to those already ordered.

Vierfontein.—This power station is erected on a coalfield about 8 miles south of the Vaal river. Twelve 210,000 lb per hour boilers and seven 30MW turbo-generators have been ordered, and with this equipment and the civil works, the estimated cost is £11,010,000. It is expected that the first set will operate early in 1953. Turbine house steelwork for the first three sets was erected during 1951, and work is proceeding on the erection of the first three boilers. The pump house on the Vaal river, with 8½ miles of 18in diameter pipeline to the power station, came into operation early in 1952, with a temporary pump. Negotiations have reached an advanced stage for the ordering of an additional five boilers and three turbo-generators, to bring the total station capacity to 300MW.

West Bank, No. 2.—The estimated cost of this power station at East London is £2,362,000. Erection of boilers is due to begin early in 1953, and to be completed by the middle of 1954, the first turbo-generator being expected to be operating during the second half of 1954. The new station is designed for an ultimate capacity of 90MW.

Wilge.—The project for Wilge power station is intended to replace the abandoned Rosherville extension project. During 1951 it became apparent that the proposed extensions at Rosherville would be inadequate to meet the additional loads; the site was also unsuitable for the additional plant required. It was therefore decided to transfer the plant on order to the site of a new power station to be known as Wilge, to be constructed near the new Largo colliery, near Kendal, Transvaal. The planned capacity of the station is 180MW, comprising two 30MW and two 60MW turbo-generators with four 150,000 lb per hour and four 400,000 lb per hour boilers, and it is estimated to cost £10,327,000. The initial installation of one 30MW turbo-generator and two 150,000 lb per hour boilers is due to be in operation by September, 1953, with the second 30MW turbo-generator set and two additional 150,000 lb per hour boilers ready by August, 1954. It is planned to have the station completed by the end of 1955.

Queenstown Power Station

Work has started at the Queenstown power station on erecting two new boilers. This plant and a new turbo-alternator, which should be installed by next winter, will, it is hoped, remove the threat of power cuts for some years to come. The contractors engaged on this work have built temporary workshops and their workmen have been busily engaged on sorting out and preparing the large number of components which go to make up the necessary equipment. A few months ago a condenser for the new turbine was received by rail. This item, which weighs over 13 tons, is beyond the capacity of the power station's 5-ton crane, so that it is being moved into a specially prepared foundation that has been cut out of the rock. The turbine-house is at present being lengthened 56ft and will include rails for the crane, so that it can move over the extended area. The crane must be capable of operating over the extra 56ft before erection starts.

Stanger Hydro-Electric Scheme

The hydro-electric scheme at Stanger, was officially opened during July. It is 12 miles from Stanger on the Umvoti River and cost £125,000. There are two 500kW turbo-alternators in the power station. Five miles of river have been cut off and a tunnel has been built through a hillside. The tunnel is 3000ft long and is 8ft 6in by 3ft 6in in cross-section. There is a head of 100ft. There are 40 miles of H.T. cable included in the scheme carrying electricity at 11kV. The new station will probably enable a cut of 25 per cent to be made in the local electricity tariff.

Industrial and Labour Notes

Britain's Overseas Trade

Full details of the United Kingdom's overseas trading in October are given in the *Trade and Navigation Accounts*, which were published by H.M. Stationery Office at the end of last week. The final figure given as the value of exports of United Kingdom goods in October is £218,772,000, or 14 per cent above the monthly average in the third quarter of this year. The Board of Trade says that, allowing for an extra working day in October, the daily rate of exports was 10 per cent higher than the third quarter average, and it is estimated that the increase of volume was of about the same order. Despite the sharp increase in October over the third quarter, however, the daily rate of export was still 5 per cent less than in the second quarter and 7 per cent below the figure for October, 1951.

The October increase, compared with the third quarter average, was of the order of £27,000,000, and was shared by all the main groups of exports. There was a substantial increase in the value of textile exports, and another significant increase—27 per cent above the third quarter's average—occurred in exports of iron and steel and manufactures thereof. Exports of non-ferrous metals were 29 per cent higher in value than the average for the third quarter. For engineering products generally there was only a small increase—9 per cent—in exports in October, compared with the third quarter's average, and they thus remained below the high rates recorded in the first half of this year. Machinery exports in October totalled £35,000,000, compared with £33,000,000 a month in the third quarter, but £36,000,000 in the first half of the year, while the two smaller groups of engineering products—electrical goods and cutlery, implements and instruments—were also higher than in the third quarter, but below the figures for the first half of the year. Exports of vehicles (including locomotives, ships and aircraft) in October increased to £40,000,000, compared with £35,000,000 a month in the third quarter and £44,000,000 in the first half-year. In this group, exports of cars, commercial vehicles (including tractors) and parts totalled £22,000,000, which was a little higher than the monthly average in the third quarter, but about £4,000,000 below the monthly average for the first half-year. The steady increase in coal exports this year continued in October, the total sold overseas being 1,213,000 tons, valued at £5,800,000. The average monthly value of coal exports in the third quarter was £5,300,000, and in the first half of the year £4,100,000.

The British Motor Vehicle Industry

In a statement circulated with the annual report of Rootes Motors, Ltd., the chairman, Sir William Rootes, claims that there is no longer any justification for retaining as an anti-inflationary measure the present purchase tax on motor-cars and commercial vehicles. It is, Sir William says, a burden on industry and the country in general and, as such, adversely affects the cost of industry. The Government should realise, the statement continues, that a flourishing home market is a necessary foundation for volume production without which we cannot continue to sell our goods overseas at competitive prices.

Sir William goes on to say that the all important problem confronting industry and, indeed, the nation as a whole is whether or not we can adjust ourselves to the highly competitive position that is becoming more and more evident, both at home and overseas. This, in short, means making better and better products available at lower and lower prices to more and more people. The Government must show greater initiative in adapting itself to the new world conditions, which means that the nation cannot sell unless it buys. We have outlived the period of restrictive economy, Sir William asserts, and it now undermines the foundations of our international trade

Elsewhere in his statement Sir William comments on the burden of taxation No progressive business enterprise, he says, can reconcile itself to a state of affairs which demands that out of its earnings no less than 66 per cent has to be handed over in direct tax alone. Whilst saying that he is "conscious of the necessity of providing the Exchequer with funds for major national issues, such as rearmament and a sound social service," Sir William asserts that if current rates of taxation continue industrial enterprise will lose vitality, and employment and national prosperity will decline.

Private Trading in Zinc

In these notes on October 31st, reference was made to a statement by Lord Swinton about the Government's intention to terminate public trading in zinc. He then said that it was hoped to permit the resumption of private trading as from January 1st next. The Ministry of Materials has now made sufficient progress in its discussions with the parties concerned to confirm that date.

The Directorate of Non-Ferrous Metals, Rugby, will terminate its existing sales arrangements for zinc on December 31st. If they wish, consumers will be able to purchase in December zinc for delivery in January on the Ministry's usual sales terms. The committee of the London Metal Exchange has informed the Ministry of Materials that dealings in zinc will begin on January 2, 1953, as January 1st is traditionally a closed day for the market.

The Ministry of Materials wants it to be known that its policy is to release from its stocks not more than a relatively small tonnage of zinc for sale during the early months after the resumption of private trading. Arrangements for the disposal of Ministry stocks have been arrived at in full consultation with producers and consumers and members of the London Metal Exchange. The zinc to be disposed of will be made available through the London Metal Exchange and other normal trade channels and will be adequate to meet consumers' requirements. A further announcement is to be made concerning import and export licensing arrangements.

The Nationalised Industries

There has been published this week a booklet entitled "The Nationalised Industries," which has been prepared by Mr. S. J. L. Hardie, former chairman of the Iron and Steel Corporation of Great Britain, and, for a time, a member of the British Transport Commission. In it, Mr. Hardie has set out his views on the basic organisation, co-ordination and control of the nationalised industries. Before doing so, however, he expresses the opinion, in an introduction to the booklet, that "insufficient time has elapsed since the transfer of these industries to public ownership for them to have assumed their permanent or long-term form, or for the full advantages of nationalisation to have been reaped."

The booklet says that it would be difficult—and in some cases impossible—to undo the nationalisation of a "living industry," and adds that "it is better to go forward to an improved method of nationalisation than attempt to go back." That, Mr. Hardie believes to be true of all the nationalised industries of this country. He comments that, in both steel and transport, capital requirements for development and expansion are so great that only a national corporation can carry them out, and goes on to say that "the capital investment programmes may have to be carried through regardless of the immediate profit to be derived by the undertakings in question."

After his general discussion of nationalisation Mr. Hardie makes, in the booklet, a recommendation for the establishment of an "Independent Nationalised Industries Board." He envisages as its function control of the policy, finance and organisation of the nationalised industries. Such a board, Mr. Hardie advocates, should be responsible to Parliament through a non-departmental Minister, and would be interposed between the Minister and the boards of the individual industries. All the boards, Mr. Hardie contends, should be preserved from "non-expert interference and the Civil Service approach." Members of them all—including the independent board—should be qualified experts with functional responsibilities, able to give guidance to the boards on specialised and technical matters instead of leaving them to unqualified secretarial staffs. At the same time, Mr. Hardie thinks that his proposed independent board might advise the Government on nationalisation or denationalisation policy. For, he says, "the question of public or private ownership becomes less and less one to be decided by reference to political doctrine, and more and more one to be decided by purely technical, financial and economic considerations."

One section of the booklet deals specifically with the iron and steel industry. In the course of it, Mr. Hardie refers to the vast capital expenditure necessary for the nationalisation and integration of iron and steel production, and comments that, without it, the industry will be unable to cope with the increasing demand. The long-term planning and modernisation of the industry to develop its maximum capacity with concentration of specific products into individual works can, in Mr. Hardie's opinion, only be effectively obtained if co-ordinated as a national programme.

Steel Prospects

In a report on the steel situation, which is included in the November issue of *Bulletin for Industry*, published by the Treasury, it is stated that recently the outlook has improved considerably. In the first ten months of this year, crude steel output was nearly 2 per cent above the 1951 level. Since May, there has been a strong upward trend and by September–October steel production was 9 per cent up on last year. The report says that there is now little doubt that this year's steel output will top the 16,000,000 tons mark, compared with 15,640,000 tons in 1951. Providing there are no unexpected difficulties over raw materials, steel output next year should beat the 1950 record of 16,250,000 tons by a substantial margin.

The main factor in the rapid rise in crude steel output, of course, has been the expansion of pig iron production. This, the *Bulletin* points out, is offsetting the decline in supplies of imported scrap, which in recent years has been such an important part of the British steel industry's raw material. In the first ten months of this year, pig iron output was nearly 10 per cent greater than in the same period of 1951. During the last eighteen months seven new blast-furnaces have been blown in and another three are shortly to come into blast. On average these new furnaces have taken about three and a half years to build and they were part of the industry's 1946 development plan. This increase in pig iron output has been readily absorbed in steel-making furnaces whose capacity has been progressively increased. A third factor, the *Bulletin* adds, is the home scrap drive which has helped to offset the cut in German supplies. Shortage of blast-furnace coke certainly hindered pig iron production in the early part of the year, but this has now been largely overcome mainly as the result of rising production and a reduction in supplies to other consumers. It is stated that the position has now improved sufficiently to allow some rebuilding of stocks at blast-furnaces and coke ovens.

About steel allocation, the report says that although some important users are still getting much less than they want, the rising trend of finished steel supplies has made some relaxations in the allocation scheme possible. Major industries in which allocations have been increased are the motor vehicle industry and shipbuilding. In both these industries the shortage of steel has been restraining output.

Notes and Memoranda

Rail and Road

SWEDEN'S "RULE OF THE ROAD."—According to *The Anglo-Swedish Review*, the transport research commission of the Swedish Academy of Engineering Sciences is trying to work out a practical and inexpensive plan for switching from the present style of driving on the left of the road to right-side traffic as in most Continental countries. The commission's first estimate of the cost of such a change was announced as being 150 million kronor (over £10,000,000 sterling).

HIGHWAYS ENGINEERING APPOINTMENTS.—The Minister of Transport has made the following appointments:—Mr. L. W. H. Savage, B.Sc., M.Eng., A.M.I.C.E., to be divisional road engineer for the North Midland Division, in succession to Mr. E. O. Blunden, M.I.C.E., who is retiring on December 31st; and Mr. J. Edgar Jones, M.Sc. (Eng.), M.I.C.E., to be divisional road engineer for the Midland Division, in succession to Mr. J. E. Cardell, A.M.I.C.E., when he retires in May, 1953.

EXPERIMENTAL PNEUMATIC BUFFER.—British Railways announces that as an experiment it proposes to fit 250 13-ton wagons with a new design of oil-pneumatic buffer, which is expected to reduce the "shock" to less than a quarter of that sustained with the normal spring buffer. The construction of the new buffer is based on experience with aircraft landing gear and relies on the compression of air by oil to cushion impact. In addition to minimising shock, the fitting of these buffers will reduce the weight of each wagon by about 750 lb.

RAILWAY SAFETY.—The Minister of Transport was asked on Monday to recommend the establishment of a Royal Commission to inquire and report on the betterment of safety precautions on the railways. In a written reply, the Minister has intimated that he is in close touch personally and through the Railway Inspectorate with the British Transport Commission and the Railway Executive on the important question of safety precautions on the railways. He does not consider that a Royal Commission would be the best way to advance our knowledge or secure further progress.

A TRACK-TESTING COACH.—A track testing coach which is being lent by the French National Railways to the British Railways records irregularities of track levels. The mechanism in this coach is fitted with moving bands of paper on which pens, connected to the wheels and to feelers touching the side of the rails, record imperfections of the track over which the coach is passing. The paper bands are marked with the mile-posts, so that it is possible immediately to locate the exact spot of any defect. The coach has sixteen wheels. It is due to arrive in this country on the Zeebrugge-Harwich Ferry by the end of November and it will be attached to ordinary passenger trains for some tests.

NEW SIDINGS AT RAINHAM.—The Eastern Region of British Railways announces that additional siding accommodation is to be provided at Rainham goods yard, where the tonnage handled over the past few years has shown a steady increase and the present facilities are insufficient to meet the traffic needs. The scheme allows for an additional siding to hold thirty-five wagons in the lower yard and the extension of two existing sidings to hold thirty-four wagons each, widening of the cart roadway from 18ft to 30ft, and an extension to correspond with the increased length of sidings. A shunt neck to hold thirty-eight wagons is also to be provided to enable the lower yard to be shunted without occupying the main line.

Miscellanea

CENSUS OF PRODUCTION REPORTS.—Two further volumes are now available in the series of final reports on the Census of Production, 1948. They are *Shipbuilding and Ship Repairing* (price 3s.), and *Machine Tools* (price 3s. 6d.). Both reports are available from H.M. Stationery Office.

WOOD PRESERVING CONVENTION.—The British Wood Preserving Association has announced that its next annual convention will be held at Trinity College, Cambridge, from June 24 to 26, 1953. Preliminary information about this event is obtainable from the headquarters of the Association, 6, Southampton Place, London, W.C.1.

MODEL BUILDING BYELAWS.—New model building byelaws designed to allow as much freedom as possible in the use of new materials and methods have been issued by the Ministry of Housing and Local Government for the guidance of local authorities. They will, it is hoped, encourage more efficient building techniques and the better use of materials.

SEARCH FOR OIL.—The prospecting subsidiary of the Anglo-Iranian Oil Company, Ltd., the D'Arcy Exploration Company, in its search for oil is to drill, in Iraq, a test well, in Chia Surkh, in the Khanaqin area, and another nearby at Naft Khaneh. In Papua a test well, drilled to gain geological information, has reached a depth of 10,500ft and in the Caunton area of Nottinghamshire a well is being drilled to search for a possible extension of the present field.

INSTITUTION OF GAS ENGINEERS.—At the opening of the annual two-day research meeting of the Institution of Gas Engineers, on Tuesday last, the president, Mr. G. E. Currier, announced that H.R.H. The Duke of Edinburgh had graciously consented to become an honorary life member of the Institution. The president said that this further example of the keen interest taken by His Royal Highness in the greater application of science and research to the development of our industries and in the suitable training of professional engineers was particularly appreciated, since the Institution of Gas Engineers, which was founded in 1863, was expressly entrusted by its Royal Charter with the furtherance of those objects.

MINING TIMBER IMPORTS.—The President of the Board of Trade has stated that, during the first nine months of this year, imports of pitprops amounted to 547,000 piled cubic fathoms valued at £24,121,000, compared with 292,000 piled cubic fathoms, valued at £9,516,000 in the corresponding period of 1951. Imports of other pitwood during the corresponding periods amounted to 10,400 tons valued at £106,000,, and 10,700 tons, valued at £92,000, respectively.

MECHANICAL HANDLING EQUIPMENT FILM.—A film, entitled "Three Installations," is now available—in 16mm and 35mm sizes—for free loan from Richard Sutcliffe, Ltd., Universal Works, Horbury, Wakefield. The film, which runs for twenty-eight minutes, has been made by the firm to portray the use of belt conveyors and their accessories in industries other than mining. The film shows the operation of three Sutcliffe installations in an ironworks, a cement factory, and a civil engineering product.

A RUBBER BONDED WIRE ROTARY BRUSH.—A. Luson and Sons, Ltd., Minerva Road, London, N.W.10, has now introduced a rubber bonded wire rotary brush for machine use. In these brushes the wire bristles are securely anchored in a vulcanised rubber cushion in addition to the normal means of fixing. The design is stated to be such that the brush is balanced, any spaces caused by loosely packed wires being taken up by the rubber, and any tendency to splay in service is counteracted. The new brushes are made in two sizes, 6in. and 8in.

STEEL DEVELOPMENT SCHEMES.—In a written Parliamentary reply, the Minister of Supply, Mr. Duncan Sandys, says that, since the war, the British iron and steel industry has entered into commitments in respect of development schemes costing just under £400 million. Of that sum, about £320 million has already been spent. The total includes schemes approved by the Iron and Steel Corporation of Great Britain amounting to about £65,000,000. The reply adds that there are certain other schemes to which approval has been given so recently that no commitment has yet been made.

OIL "SEALINE."—At St. Vincent, in the Cape Verde Islands, a new under-sea oil pipeline is now in operation. The 16in diameter pipe was prefabricated on shore and its total length is 4300ft, of which 3300ft is laid out to sea, the actual launching operation being performed in 40 minutes. The line has been laid to speed the discharge and turn round of oil tankers and the first ship to use the facilities took 30 hours to discharge 12,814 tons of oil into the storage tanks of the Shell Petroleum Company, Ltd., as against the average time of four to five days when discharging into barges.

ROYAL AGRICULTURAL SHOW, 1953.—Preparations are now being made at Blackpool for next year's Royal Show, which is to be held from Tuesday to Friday, July 7th to 10th. The site, which adjoins Stanley Park, and is about 2 miles from the sea-front, occupies about 160 acres. There is every indication that the machinery section will be as extensive and representative as usual. One item of particular general interest is that arrangements have already been made for the Royal Agricultural Society of Kenya to stage an exhibit at the Show. The Show is organised by the Royal Agricultural Society of England, 16, Bedford Square, London, W.C.1.

ADEN REFINERY.—The liner "Dorsetshire" will serve as a floating camp for those engaged in the initial work in the construction of a 5,000,000-ton refinery which is to be built at Aden by the Anglo-Iranian Oil Company, Ltd. The refinery will take about two years to build and will occupy an area of 270 acres. Among the major plant to be installed will be two atmospheric distillation units, complete with stabilisers and soda washers, a platforming unit and a sulphur dioxide extraction plant. The installed capacity of the power station will be 30,000kW and to form a turning circle and approach for the large oil tankers, delivering crude oil, it will be necessary to dredge about 5,000,000 cubic yards of sand.

DIAL SNAP AND STICK GAUGES.—We are informed by the M.P.J. Gauge and Tool Company, Ltd., Hanson's Bridge Road, Birmingham, 24, that it has added two new designs of gauges to the wide range of instruments it makes. One of the new instruments is a comparator type dial stick gauge, made in various sizes from 14in to 48in. These gauges are made retractable so that they can be introduced into recesses, and one end is telescopic so that the use of extension pieces is avoided. A new dial snap gauge is made for work measurement up to 28in and can be fitted with both flat or spherical tungsten tipped anvils. Both types of these gauges can be supplied with dials reading in 0·001in, 0·0005in, 0·0001in, or 0·01mm and 0·002mm.

EUROPE'S SOLID FUEL SUPPLY POSITION.—The coal trade sub-committee of the United Nations Economic Commission for Europe met recently at Geneva to examine supply prospects for the first quarter of 1953. The discussions showed that by and large the deficit in coke availabilities as compared with declared requirements would be about 550,000 tons. This deficit is almost equally divided between metallurgical coke and coke for other uses. As regards coal, there is a distinction between coking fines, anthracites and anthracite fines, on the one hand, and other coal categories, on the other. Europe appears to be unable to meet her own requirements of fuel in the first category. Availabilities of coking coal are 3,000,000 tons short of declared requirements. It may, however, be possible to bring that figure down somewhat when requirements have been revised and possible quality switches have been made. The deficit is about 200,000 tons for anthracite fines and about 750,000 tons for graded anthracite. On the other hand, the surpluses in the case of other coals amount to nearly 1,200,000 tons. The sub-committee is now examining the problems of supply and distribution during the first quarter of 1953 in greater detail.

COAL OUTPUT.—Coal output in Great Britain last week amounted to 4,602,200 tons, which included 4,406,200 tons from the deep mines and 196,000 tons from opencast workings. The total fell slightly below that for the corresponding week of last year. In the forty-seven completed weeks of this year, ended November 22nd, saleable coal output totalled 203,548,500 tons, compared with 200,898,100 tons in the corresponding period of last year. In the week ended November 15th the number of wage-earners on colliery books was 719,000, of whom 297,500 were face workers. A year ago the figures were 694,900 and 286,000 respectively. Distributed coal stocks on November 15th were returned as 19,457,000 tons, which was over 2,000,000 tons in excess of the figure returned on the corresponding day of 1951.

BUILDING LICENSING.—Last week, the Minister of Works, Mr. David Eccles, announced some changes in the licensing system for building. He said that early this year the volume of maintenance work of all kinds showed signs of falling off, and although from July 1st the free limit for housing and general work was raised from £100 to £200 in a period of twelve months, this did not arrest the decline. The licensing period has now been altered to the calendar year, and the current licensing period for which the limits are £500 for industrial and agricultural buildings and £200 for all other buildings, is to end on December 31st next. This means that the full amounts will be available during the period of six months. For the calendar year, 1953, the free limits will be, for industrial and agricultural buildings, £2000, and for all other buildings, £500.

THE KILN DRYING OF TIMBER.—A publication entitled *The Kiln Operator's Handbook*, by W. C. Stevens and G. H. Pratt, which has been issued by H.M. Stationery Office, is based on the special courses for kiln operators which have been held for many years at the Forest Products Research Laboratory, Princes Risborough. The book is intended to be a practical work for the guidance of operators on the working of various kinds of installation and on the behaviour during kilning of different classes of timber. An opening chapter deals with the incidence of moisture in timber and its measurement by oven drying or by electrical methods, and the early part of the book outlines the principles of kiln drying and the kilns that are used. Operators' equipment and the functioning and care of kiln instruments are described in detail. The preparation of the kiln load, the application of drying schedules and the practical details of kiln operation, including the keeping of kiln records, are discussed from the viewpoint of the practical operator, and there are separate chapters on kiln maintenance and testing. Appendices provide charts and tables of use to the operator, kiln drying schedules and information on the seasoning properties of the majority of timbers in commercial use.

Personal and Business

THE SCOTTISH REGION OF BRITISH RAILWAYS announces the appointment of Mr. G. D. D. Greig as district engineer, Inverness.

LANCASHIRE DYNAMO HOLDINGS, Ltd., announces that Mr. H. G. Carter, secretary of the company, has been appointed a director.

HERBERT LAPWORTH PARTNERS, 25, Victoria Street, London, S.W.1, have taken into partnership Mr. P. B. Mitchell, B.Sc., A.M.I.C.E.

MR. J. M. ORMSTON, formerly a director of Vickers-Armstrongs, Ltd., has joined the board of the Sunderland shipbuilding firm of S. P. Austin and Sons, Ltd.

ROBERT HUDSON, Ltd., Leeds, states that its London office has been moved to 47, Victoria Street, S.W.1 (telephone: Abbey 7127; telegrams: "Raletrux Sowest").

LIEUT.-COLONEL H. RIGGALL, D.L., deputy chairman and managing director of Ruston and Hornsby, Ltd., has been appointed a governor of Loughborough College of Technology.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., has opened a branch office, in charge of Mr. J. Taylor, at 43, Fountain Street, Manchester, 2 (telephone: Central 0758).

MR. DANIEL LONGDEN, M.R.San.I., M.I.San.E., has taken Mr. R. F. Earley, A.M.I.C.E., F.G.S., into partnership. The firm will be known as Longden and Earley, 2, Promenade Chambers, Edgware, Middlesex (telephone: Edgware 0233). Mr. Earley was, until recently, assistant chief engineer of the Stevenage Development Corporation.

ASSOCIATED COMMERCIAL VEHICLES, Ltd., states that, by mutual agreement, Sir Robert Fryars has relinquished his offices as chairman and managing director of A. C. V. Sales, Ltd., and as director of the parent company and other companies in the group. Mr. W. R. Black, managing director of Park Royal Vehicles, Ltd., has been appointed chairman of A. C. V. Sales, Ltd.

British Patent Specifications

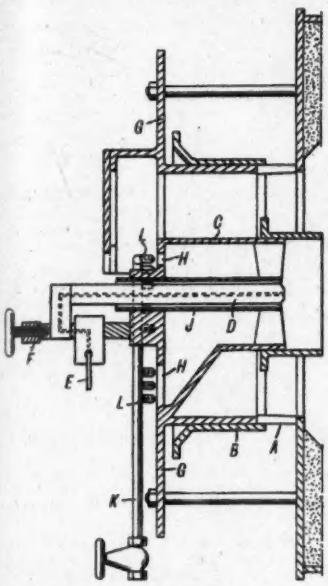
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2. 2s. 8d. each.

FURNACES

681,608. October 3, 1949.—LIQUID FUEL FURNACES, White, Tomkins and Courage, Ltd., North Albert Works, Reigate, Surrey, and Milton Dewhurst of the company's address,

The furnace shown is of standard pattern with the axial secondary air inlets *A* controlled by a baffle *B*. *C* is a burner tube housing a burner, *D* being supplied by pressure fed fuel oil by way of a supply pipe *E* and valve *F*. The support plate *G* is provided with a series of apertures *H* arranged



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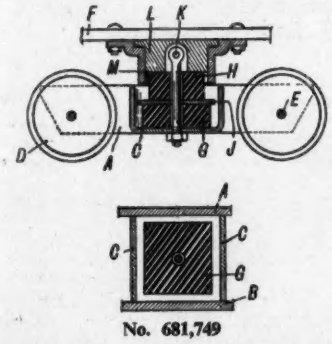
circumferentially and adjacent to the burner tube *J*. The apertures may be in groups of two or more. A steam pressure pipe *K* in front of the apertures *H* is so arranged that jets *L* coincide with axes of the apertures. When steam under pressure is admitted jets entering the apertures from the pipe form a series of ejectors. This steam under pressure passing into the furnace draws in air to produce a number of streams parallel with the axis of the burner tube.—*October* 29, 1952.

RAILWAY ENGINEERING

681,749. June 12, 1950.—BOGIE TRUCKS COMPRISING TWO WHEELS WITH PARALLEL AXLES, Forges et Ateliers de Commentry-Oissel, 16, rue Octave Feuillet, Paris, France.

Referring to the drawing, *A* and *B* are metal side plates of the bogie truck and *C* is a longitudinal "U"-section plate welded or riveted to the side plates. The wheels *D* are disposed centrally between the plates on parallel axes *E* and the vehicle body *F* is connected to the bogie truck by the device



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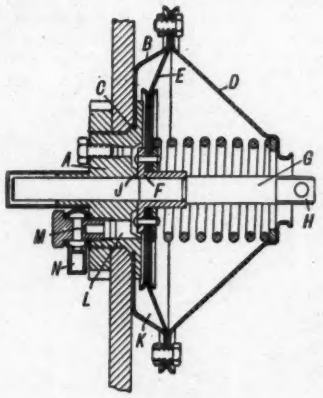
shown. Two blocks of elastic material such as rubber are mounted one upon the other in the casing formed by the plates. The lower block *G* may be square and solidly seated on the plate *C*, while the upper block *H* may be cylindrical. A sheet metal plate *J* is inserted between the two blocks. The blocks and the plates are bolted together and the head of the bolt is flattened to form an ear through which extends an axle *K* fixed in a cylindrical member *L*, the lower face of which seats directly on the block *H*. The top part of the cylindrical member *L* is formed with a flange which is located within a recess in a cylindrical bearing *M* bolted to the vehicle body at its flanged upper edge. The member *L* is free to turn in the bearing and the flange maintains it in position whilst allowing it to turn freely. This arrangement allows the elastic blocks to yield or deform under an axial load in the direction of the bolt. The bogie truck described will turn easily owing to the free movement of the member *L* in the bearing *M* and this turning capacity as well as the axial deformation provides good guiding of the truck and efficient suspension for the vehicle.—*October* 29, 1952.

INTERNAL COMBUSTION ENGINES

681,668. March 16, 1951.—A DEVICE FOR AUTOMATICALLY VARYING THE SETTING OF THE FUEL-INJECTION TIMING OF THE FUEL-INJECTION PUMP, Hans Deckel and Friedrich Wilhelm Deckel, Waakirchner-Strasse 7-13, Münich 25, Germany.

The invention relates to a device comprising a control membrane coupled with the timing means and influenced by a pressure which is dependent on the engine speed. In the drawing, *A* is a carrier to which a casing element *B* of sheet metal is attached by bending at *C*. The casing element is attached to a cover plate *D* of sheet metal. Between the two casing parts there is inserted a circular membrane *E*, the middle portion of which is attached to a flanged bush *F* by washers and rivets. This bush is fixed on a control shaft *G*, which is movably supported in the carrier *A* and the end *H* of which is connected by rods with the timing means of a fuel-injection pump. A spring abutting against the cover plate and one of the washers of the membrane tends to move the membrane with the control shaft into the left-hand end position in which the bush *F* bears against a stop *J* of the carrier. The working or fluid chamber *K* of the device is connected by an opening *L*, a throttle aperture *M* and a pipe



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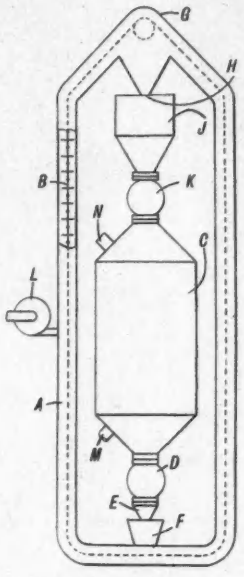
connected to the ring *N*, with a pressure transmitter driven by the engine, e.g. the supercharger of an internal combustion engine. The pressure in the working chamber varies thereby with engine speed. When the engine is at rest the movable elements of the device are in their rest positions shown in the drawing, in which the fuel-injection timing is set to "Retard." When the engine is started the pressure in the working space *K* will increase with the engine speed and will act correspondingly on the membrane *E*. This causes a displacement of the shaft *G* against the action of the spring, which correspondingly actuates the fuel-injection timing means and advances the timing. The setting of the fuel-injection timing, varying linearly with the pressure in the chamber *K* or the engine speed, respectively, is restricted in the "Advance" direction by the striking of the washer of the membrane against the casing.—*October* 29, 1952.

MISCELLANEOUS

681,551. July 26, 1949.—PURIFICATION OF GASES, Humphreys and Glasgow, Ltd., 22, Carlisle Place, London, S.W.1. (*Inventor: Ian Hugh Phillipps.*)

The invention is concerned with means for revivification of fouled purification material after it has been removed from a gas purification chamber, and has for its object "external" revivification without the necessity for a separate vessel or vessels. As the drawing shows, the elevating and aerating of the fouled purification material takes place in the substantially air-tight conduit *A* which encloses an endless conveyor *B*, of the drag-link, scraper or chain type. The fouled purification material passes from the purifier *C* through a rotary valve *D* and discharge nozzle *E*, into the receiver *F*, whence it passes directly to the conveyor *B*, which raises it in the form



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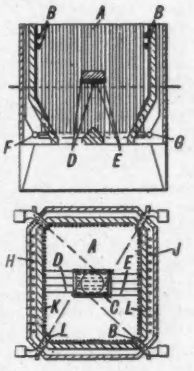
of a column and delivers it at *G*, first through discharge chute *H* into hopper *J*, and thence through a rotary valve *K* into the chamber *C*, the conveyor chain returning empty down the other limb of the endless conduit. Air from the blower *L* is introduced into the conduit and is forced upwards and downwards through the rising column of purification material, thereby effecting its revivification. By means of suitable apparatus the moisture content and pH of the material delivered to the hopper *J* may be adjusted before it is returned to the gas purification chamber *C*. The gas for purification may be passed through chamber *C* either in counter-current to the downwardly moving mass of purification material or in co-current flow with it, the pipes *M* and *N* serving either for exit or for entry of the gas.—*October* 29, 1952.

STEAM GENERATORS

681,640. September 29, 1950.—TUBULAR BOILERS, Babcock and Wilcox, Ltd., Babcock House, Farringdon Street, London, E.C.4.

As shown in the drawings, the combustion chamber *A* is corner fired with pulverised fuel by the burners *B* and a block or table *C* of heat storing material providing an ignition surface is arranged slightly below the plane of combustion. The table is supported by two interlocked groups of cooling tubes *D* and *E*, which extend from distributors *F* and *G*, supplied with water from a boiler drum by means of downcomers *H* and *J*. The groups of tubes *D* and *E* cross one another at some distance below the table and immediately below the table are given reverse bends so that the tubes *D* extend below and beyond the table, at a slight upward inclination, to the combustion chamber wall *K* which the tubes help to line. The tubes *E* extend below and beyond the table, at a slight upward inclination, to the combustion chamber wall *L* which they help to line. Extending also from the distributors are cooling tubes which rise along the hopper walls and complete the tube screens of the walls *K* and *L*. The table supporting tubes are merely specially formed combustion chamber wall cooling tubes. The



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arrangement described possesses the merit of simplicity, but it has the disadvantage that the tubes *D* and *E* form cooling surfaces at opposite sides of the table *C*, which, as a result of absorption of heat radiated from the ignition zones of the flames, partially nullify the effect of the ignition surface. Therefore, the tubes are arranged as far as possible from the burners, but this restricts the extent of the ignition area. In the specification modified designs for other types of tubular boiler are also shown.—*October* 29, 1952.

Launches and Trial Trips

BRIER ROSE, coaster; built by John Lewis and Sons, Ltd., for Hughes-Holden Shipping, Ltd.; length between perpendiculars 170ft, breadth moulded 30ft, depth moulded upper deck 12ft 9in, quarter deck 16ft 3in, deadweight 800 tons; Mirrlees diesel engine, 600 b.h.p. at 250 r.p.m., two 40kW generators. Launch, November 4th.

CEDRIC, refrigerated cargo liner; built by Harland and Wolff, Ltd., for Shaw Savill and Albion Company, Ltd.; length between perpendiculars 481ft, breadth moulded 69ft, depth moulded to shelter deck 41ft 6in, gross tonnage 10,800; three steel decks and eight watertight bulkheads, six main cargo holds, Nos. 1 and 6 are for general cargo, derrick complement includes one of 50 tons and one of 25 tons capacity, electric deck machinery; two Harland and Wolff, single-acting, two-stroke, opposed-piston diesel engines, cylinders 750 mm diameter by 2000 mm combined stroke, four 320kW diesel generators. Trial November.

GUILDFORD, motor collier; built by the Burntisland Shipbuilding Company, Ltd., for the South Eastern Gas Board; length between perpendiculars 264ft 6in, breadth 39ft 6in, depth moulded 18ft 6in, deadweight 2875 tons, draught loaded 17ft 1in; British Polar diesel engine, eight cylinders, 340 mm diameter by 570 mm stroke, 1150 b.h.p. at 225 r.p.m. Launch, November 17th.

OBUASI, cargo liner; built by Harland and Wolff, Ltd., for Elder Dempster Lines, Ltd.; length between perpendiculars 415ft, breadth moulded 60ft, depth moulded to shelter deck 34ft, gross tonnage 5600; two steel decks, seven water-tight bulkheads, four main cargo holds, derrick complement includes one to lift 50 tons and one to lift 30 tons; Harland and Wolff–B. and W. two-stroke, single-acting, opposed-piston diesel engine, five cylinders 620 mm diameter by 1870 mm combined stroke, four 125kW diesel generators. Trial November 13th.

CALTEX LIVERPOOL, oil tanker; built by R. and W. Hawthorn Leslie and Co., Ltd., for the Overseas Tankship (U.K.), Ltd.; length overall 544ft 4in, breadth moulded 70ft, depth moulded 39ft 9in, deadweight 17,250 tons; one pump room, three horizontal cargo oil pumps and three vertical duplex cargo oil stripping pumps, steam deck machinery; a single set double-reduction geared turbines of 8200 s.h.p., steam supplied at 450 lb per square inch and 750 deg. Fah. by two Yarrow three-drum boilers, two 400kW geared turbo-generators, trial speed 15 knots. Trials November 12th and 13th.

Technical Reports

The Collapse Method of Design. London: British Constructional Steelwork Association, Artillery House, Westminster, S.W.1.—This publication is the first of a series, outlining a method of design calculated to appeal to the structural designer, which is based upon the plastic theory as developed by the well-known work of Professor Baker and his research team. There are five chapters dealing, respectively, with: the plastic theory and the collapse method of designing single-span beams; continuous beam problems; the design and analysis of rectangular pinned-base portals; portals with pinned-base and ridge roofs; and problems concerned with combined axial and bending loads. An appendix deals with the calculation of the plastic moduli of sections.

Studies in Composite Construction, Part 1: The Composite Action of Brick Panel Walls Supported on Reinforced Concrete Beams. London: D.S.I.R., H.M. Stationery Office. Price 2s.—It has been usual in designing buildings to consider the framework as bearing the loads and stresses of the building. No account has normally been taken of the stiffening effect upon the completed structure of the walls and floors and the partial rigidity of joints. These effects have now been found to increase the strength of the building as a whole. The behaviour of composite structures is complex and it is not always possible to forecast their carrying capacity. The Building Research Station is making a study of the behaviour of these structures and the present publication is the first of a series which will deal with the subject. The work described included laboratory experiments and observation of buildings during erection and after completion, but the results are concerned only with the stiffening effect of brick walls. By taking into consideration the action of composite construction in strengthening the complete building considerable economy in steel can be achieved, it is stated. The series of tests described in the paper sought to determine the minimum amount of steel which would be required for the reinforcing of houses carried on short bored piles, but the results have been analysed in such a way as to be of more general interest to the structural engineer.

DOMESTIC HOT WATER.—The results of two surveys made by the Chief Scientific Adviser's Division of the Ministry of Works on the use of water heating appliances in summer is given in Special Report No. 14 of the National Building Studies, published by H.M. Stationery Office; the report costs 3s.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on or before the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Dec. 1st.—N.E. LONDON BRANCH: Angel Hotel, Ilford, "General Installations," H. W. Quelch, 8 p.m.

Tues., Dec. 2nd.—S.E. LONDON BRANCH: Congregational Church Hall, Court Road, Eltham, "The Camera in Industry," 8 p.m.——W. LONDON BRANCH: Windsor Castle Hotel, 134, King Street, Hammersmith, W.6, "Ductube System in Structures," 7.30 p.m.——NOTTINGHAM BRANCH: E. Midland Electricity Board, Smithy Row, Nottingham, "Power Factor Correction," G. Knights, 7.30 p.m.

Wed., Dec. 3rd.—N. LONDON BRANCH: Three Jolly Butchers' Hotel, Wood Green, N.22, "Jet Engines," A. C. Parkes, 8.15 p.m.

Mon., Dec. 15th.—N.W. LONDON BRANCH: Prince of Wales Hotel, Kingsbury, "The Maintenance of Electric Lifts," 8 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., Dec. 4th.—SCOTTISH SECTION: Department of Natural Philosophy, The University, Edinburgh, "The London to Kirk o'Shotts Television Cable/Radio Link System," J. H. H. Merriman, 7 p.m.

Tues., Dec. 9th.—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, programme of Technical Films, 7.15 p.m.

CLEVELAND INSTITUTION OF ENGINEERS

Mon., Dec. 1st.—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Development in the Rolling of Broad Flange Beams at Cargo Fleet," G. Barry Thomas, 6.30 p.m.

ENGINEERS' GUILD

Thurs., Dec. 4th.—METROPOLITAN BRANCH: Caxton Hall, Westminster, London, S.W.1, Films, "Rig 20," "Zonguldak Harbour," "Wealth of the World, Oil," 6 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Dec. 2nd.—Church Institute, Albion Street, Hull, "Technical Libraries a Justification," Miss J. Binns, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Wed., Dec. 3rd.—EDINBURGH CENTRE: Lighting and Cleansing Department, 357, High Street, Edinburgh, "Vision and Illumination," A. Mellick, 7 p.m.——NEWCASTLE CENTRE: Minor Durant Hall, Oxford Street, Newcastle upon Tyne, 1, "Brightness Engineering," W. Robinson, 6.15 p.m.

Thurs., Dec. 4th.—GLASGOW CENTRE: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "Vision and Illumination," A. Mellick, 6.30 p.m.——NOTTINGHAM CENTRE: E. Midlands Electricity Board, Smithy Row, Nottingham, "Street Lighting Practice," J. Woodhouse, 6 p.m.——BRADFORD GROUP: Yorkshire Electricity Board, 45–53, Sunbridge Road, Bradford, "Illumination and Illusion," P. Hartill, 7.30 p.m.——EXETER GROUP: Providence Hall, Northernhay Street, Exeter, "The Architect's Approach to Artificial Illumination," R. G. Cox, 7 p.m.

Fri., Dec. 5th.—BATH AND BRISTOL CENTRE: S.W. Electricity Board Lecture Theatre, Old Bridge, Bath, "The Architect's Approach to Artificial Illumination," R. G. Cox, 7 p.m.——HUDDERSFIELD GROUP: Electricity Showroom, Market Street, Huddersfield, "Lighting Ideas for the Home," Miss M. D. Wardlaw, 7.15 p.m.

INCORPORATED PLANT ENGINEERS

Tues., Dec. 2nd.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, W.C.2, "Steam versus High-Pressure Hot-Water Installations," B. Pheasant, 7 p.m.——S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Mechanical Handling Problems," 7.15 p.m.

Wed., Dec. 3rd.—SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, "High-Speed Diesel Engines in Mobile Plant," A. V. Driver, 7.30 p.m.

Thurs., Dec. 4th.—PETERBOROUGH BRANCH: E. Gas Board's Demonstration Theatre, Church Street, Peterborough, "Modern Dairy Plant," C. H. Macquire, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Thurs., Dec. 4th.—LONDON BRANCH: Institute of Metals, 4, Grosvenor Gardens, S.W.1, "Mould Reaction," R. W. Ruddle, 7 p.m.

INSTITUTE OF ECONOMIC ENGINEERING

Sat., Dec. 6th.—The Christian Institute, 70, Bothwell Street, Glasgow, "Overheads," C. W. Spence, 10.30 a.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Dec. 2nd.—JUNIOR LECTURE: Queen Mary College, Mile End Road, London, E.1, "Construction of Oil Tankers," H. Armstrong, 4 p.m.

Thurs., Dec. 4th.—JUNIOR LECTURE: Technical College, Wimbledon, "Construction of Marine Boilers," A. P. Monk, 7.30 p.m.

Tues., Dec. 9th.—85, Minories, London, E.C.3, "Some Unusual Ship and Machinery Defects: Their Investigation and Cure," 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Dec. 1st.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Selection and Characteristics of a Marine Engine," H. Brady, 7.30 p.m.

Tues., Dec. 2nd.—EASTERN CENTRE: Swan Hotel, Bedford, "Specialised Vehicles for Road Transport," L. D. Watts, 7 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Thurs., Dec. 11th.—Smithfield Show and Agricultural Machinery Exhibition, Richmond Hall, Earl's Court, London, "Fans in Agriculture," W. Cover and R. C. Dick, 4.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., Dec. 2nd.—S. WALES CENTRE, GRADUATES' AND STUDENTS' SECTION: Room 121, University College, Museum Avenue, Cathays Park, Cardiff Technical Film Show with Discussion, 7 p.m.

Wed., Dec. 3rd.—MIDLANDS CENTRE: GRADUATES' AND STUDENTS' SECTION: Visit to Chance Brothers, Ltd., Glass Works, Spen Lane, Smethwick, 40, 2 p.m.

Thurs., Dec. 4th.—YORKSHIRE CENTRE, GRADUATES' AND STUDENTS' SECTION: Technical College, Great Horton Road, Bradford, "An Account of the Factors Affecting the Efficiency of Bubble Cap Distillation Columns," J. E. Bartle, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 2nd.—STRUCTURAL AND BUILDING GROUP: Great George Street, Westminster, London, S.W.1, "The Design and Construction of the B.E.A. Hangars at London Airport, with particular reference to Prestressed Concrete," D. H. New, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Dec. 1st.—S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Colour Television: Some Subjective and Objective Aspects of Colour Rendering," G. T. Winch, 6 p.m.

Tues., Dec. 2.—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, Discussion on "Recording Instruments," opened by W. Bamford, 5.30 p.m.——LONDON STUDENTS' SECTION: Public Library, Chelmsford, Discussion Evening, 7 p.m.

Wed., Dec. 3rd.—RADIO SECTION: Savoy Place, London, W.C.2, "A Survey of Present Knowledge of Thermionic Emitters," D. A. Wright, 5.30 p.m.——SOUTHERN CENTRE: Municipal College Extension, Anglesea Road, Portsmouth, "The Logical Approach to the Problems of Space Warming by Electricity," D. H. Parry, 6.30 p.m.——NORTH OF SCOTLAND SUB-CENTRE: Caledonian Hotel, Inverness, "Amenity and Hydro-Electricity Schemes," L. B. Perkins, 7.30 p.m.——S.E. SCOTLAND SUB-CENTRE: Heriot-Watt College, Edinburgh, "The Electrolytic Analogue in the Design of H.V. Power Transformers," D. McDonald, 7 p.m.——TEES-SIDE SUB-CENTRE: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "Post-Graduate Activities in Electrical Engineering," W. J. Gibbs, D. Edmundson, R. G. A. Dimmick and G. S. C. Lucas, 6.30 p.m.

Thurs., Dec. 4th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "Economic Aspects of Overhead Equipment for D.C. Railway Electrification," O. J. Crompton and G. A. Wallace, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Tues., Dec. 2nd.—Room A5, Technical College, Coventry, "Marine Radar," M. J. Millane, 7.30 p.m.——S.W. BRANCH: Grand Hotel, Broad Street, Bristol, "Testing Metals," A. D. Mallon, 7.70 p.m.

Wed., Dec. 3rd.—Chamber of Commerce, New Street, Birmingham, "The Application of Electronics in Inspection Methods," J. R. Corelius, 7.30 p.m.

Thurs., Dec. 4th.—Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "The Gas Turbine: Its Present Position and Prospects," A. W. Pope, 6 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Dec. 2nd.—39, Elmbank Crescent, Glasgow, "Instruments and Technique in Vibration Research," D. S. Gordon, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 28th.—GENERAL MEETING: Storey's Gate, St. James's Park, London, S.W.1, "The Athlone Fellowship Scheme for Training Canadian Graduates in Great Britain," W. Abbott, 5.30 p.m.

Fri., Dec. 5th.—GENERAL MEETING: Storey's Gate, St. James's Park, London, S.W.1, "An Experimental Investigation in the Redrawing of Cylindrical Shells," S. Y. Chung and H. W. Swift; "An Experimental Investigation of the Yielding of Strip Between Smooth Dies," A. B. Watts and Hugh Ford, 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Fri., Dec. 5th.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The London-Wenvoe Experimental Radio Link for Television," W. J. Bray, R. L. Corke and R. W. White, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Sat., Nov. 29th.—YORKSHIRE GRADUATE SECTION: Great Northern Hotel, Leeds, "Measurement of Productivity," S. M. Maude, 2.30 p.m.

Wed., Dec. 3rd.—NOTTINGHAM SECTION: Victoria Station Hotel, Nottingham, "High-Speed Photography," Miss M. D. Gauntlett, 7 p.m.

Thurs., Dec. 4th.—READING SECTION: Great Western Hotel, Reading, "The Future Prospects of the Production Engineer," W. C. Puckey, 7.15 p.m.

Fri., Dec. 5th.—W. WALES SECTION: Y.M.C.A., St. Helen's Road, Swansea, "Administrative Problems of Industry," Sir Patrick Hannon, 7.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., Dec. 1st.—N.E. SECTION: Neville Hall, Mining Institute, Neville Street, Newcastle upon Tyne, "The Organisation and Function of a Rubber Service Laboratory," H. J. Sherwood, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Nov. 28th.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "Tubular Structures," E. McMinn, 6 p.m.

Tues., Dec. 2nd.—NORTHERN COUNTIES BRANCH: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough "Relaxation Methods" D. M. Brotton 6.30 p.m.

Fri., Dec. 5th.—WESTERN COUNTIES BRANCH: Geology Lecture Theatre, The University, Bristol, "The Design and Erection of Television Masts," P. J. Ward, 5.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 28th.—Townsend House, Greycoat Place, London, S.W.1, Annual General Meeting, 7 p.m.

Wed., Dec. 3rd.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Iron Making in the Black Country, Past and Present," W. K. V. Gale, 7 p.m.

Fri., Dec. 5th.—Townsend House, Greycoat Place, London, S.W.1, Film Evening, "Grain Drying," introduced by T. C. Bailey, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Nov. 28th.—Engineers' Club, Albert Square, Manchester, "Economic Review," A. Elliott, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 28th.—Mining Institute, Newcastle upon Tyne, "Springs," W. E. Frost, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Dec. 2nd.—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, "Aerodynamics of Wind Tunnel Design," J. C. Gibbings, 7.30 p.m.

Thurs., Dec. 4th.—4, Hamilton Place, London, W.1, "Air Traffic Control, To-day and To-morrow," V. A. M. Hunt, 7 p.m.

SHEFFIELD METALLURGICAL ASSOCIATION

Tues., Dec. 2nd.—Grand Hotel, Sheffield, "Some Practical Forging Aspects in the Production of Medium and Heavy Forgings," R. W. Brocklehurst, 7 p.m.

SOCIETY OF ENGINEERS

Mon., Dec. 1st.—Geological Society, Burlington House, Piccadilly, London, W.1, "The Fatigue of Metals: Facts and Theories Reviewed," B. R. Byrne, 5.30 p.m.